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FOCUS

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THE 10 WORLD CHANGING EXPERIMENTS THAT WILL SHAPE THE FUTURE

AND AFFECT EVERY SINGLE PERSON ON THE PLANET INCLUDING YOU

Freefall from space
Why this man's jump from 120,000ft could save future astronauts

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Iain Stewart
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Welcome

Summer 2012

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Already a subscriber? Turn to page 30 for an exclusive interview with nano-technologist Eric Drexler

Great experiments tend to stick in your mind. I learned about the Michelson-Morley experiment at school, but it was years before I grasped its full implications – that the evidence uncovered by the two Americans paved the way for the theory of relativity.

There have been plenty like that in the past, but what about the future? Which experiments being planned today will shape the world of tomorrow? In this issue we've scoured the cutting edge of science to find the projects that could change our lives. We even rank them, starting on page 52, in order of importance. And if you don't agree with our ranking, send me an email or tweet, or post on our Facebook wall to tell us which experiments you think will have the greatest impact. I look forward to publishing your comments.

While humankind has shaped the world, some natural phenomena may never be tamed. Take volcanoes. They inspire fascination and fear in equal measure, and from 9 to 12 July they'll be the focus of a BBC programme, *Volcano Live*. Presenters Kate Humble and Professor Iain Stewart will broadcast live from Hawaii's Kilauea volcano. Kilauea will (hopefully) be completely safe – but other volcanoes are far more deadly. We round up five of the most dangerous on page 42, and speak to Iain Stewart about his love of all things lava on page 48.

I'm not sure I'd want to stand on top of a volcano, and I'd be even less happy to jump out of a balloon at 120,000 feet. That's halfway to the edge of space! Felix Baumgartner is made of sterner stuff, though, and this summer you'll be able to follow his fortunes on the BBC as he attempts to break the world record for the highest ever skydive. On page 32 we reveal how the technology in Felix's suit could one day benefit astronauts.

There's far more in this issue besides, from the future of social networks to the science of skin and a new gadget that can calculate exactly how many calories you burn during the day. In my case, probably not enough...

Until next issue,

Graham

What I've found out this month

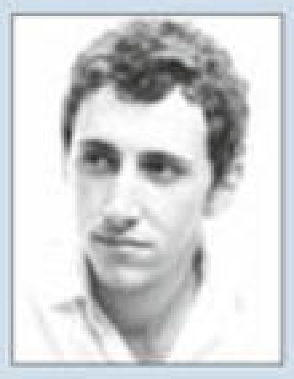
- Our fingerprints have sensors that detect five different things (p71)
- Science might be able to improve on photosynthesis, which could in turn help to feed the world (p60)
- Mount Rainier in the US could cause devastation by unleashing mud (p43)

Experts

Hannah Devlin
Hannah is the science editor of *The Times*. On p70, she reveals 10 things you probably didn't know about your own skin… such as the fact it can pump out up to eight litres of sweat a day. Nice.

Dr Paul Parsons
In this month's cover feature, science author and former *Focus* editor Paul looks at some of the most exciting and potentially game-changing experiments taking place in laboratories around the world.

Bill McGuire
Bill is Professor of Geophysical and Climate Hazards at UCL. With *Volcano Live* on TV this month, we asked him to name the world's most dangerous 'weapons of mass eruption'. Read his top five on p42.



Ian Taylor
Another former *Focus* staffer, Ian is currently at *Men's Health*. With his new expertise in pushing your body to its limits, who better to get the story (p32) behind a daredevil attempt to freefall from space?

The *Big Book Of Answers* app collects the very best questions from the *Focus* Q&A section and adds a sprinkling of incredible Megapixel images. To download it, visit the App Store and enter 'Big Book of Answers' in the search box.

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COVER: ILLUSTRATION BY SAM FREEMAN

Summer 2012

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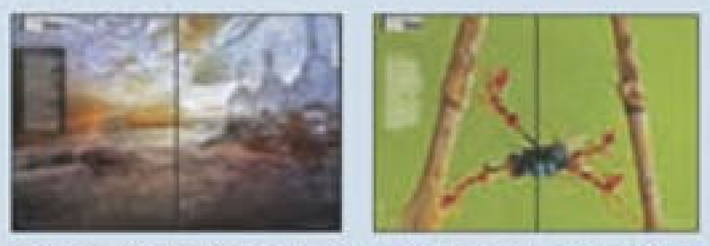
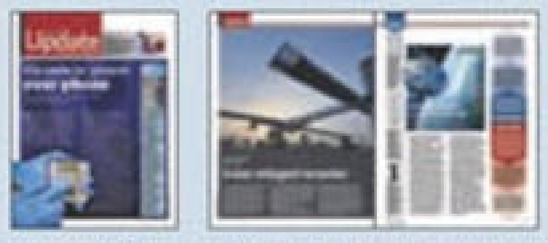


MegaPixel 8
Amazing images of the world around us as you've never seen it before



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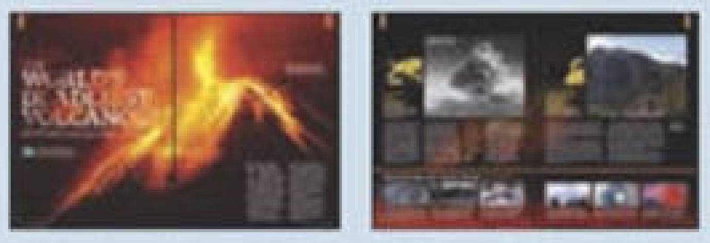

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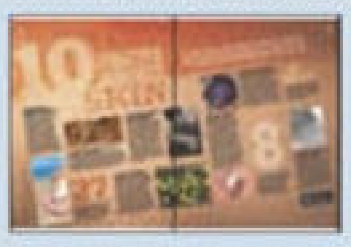

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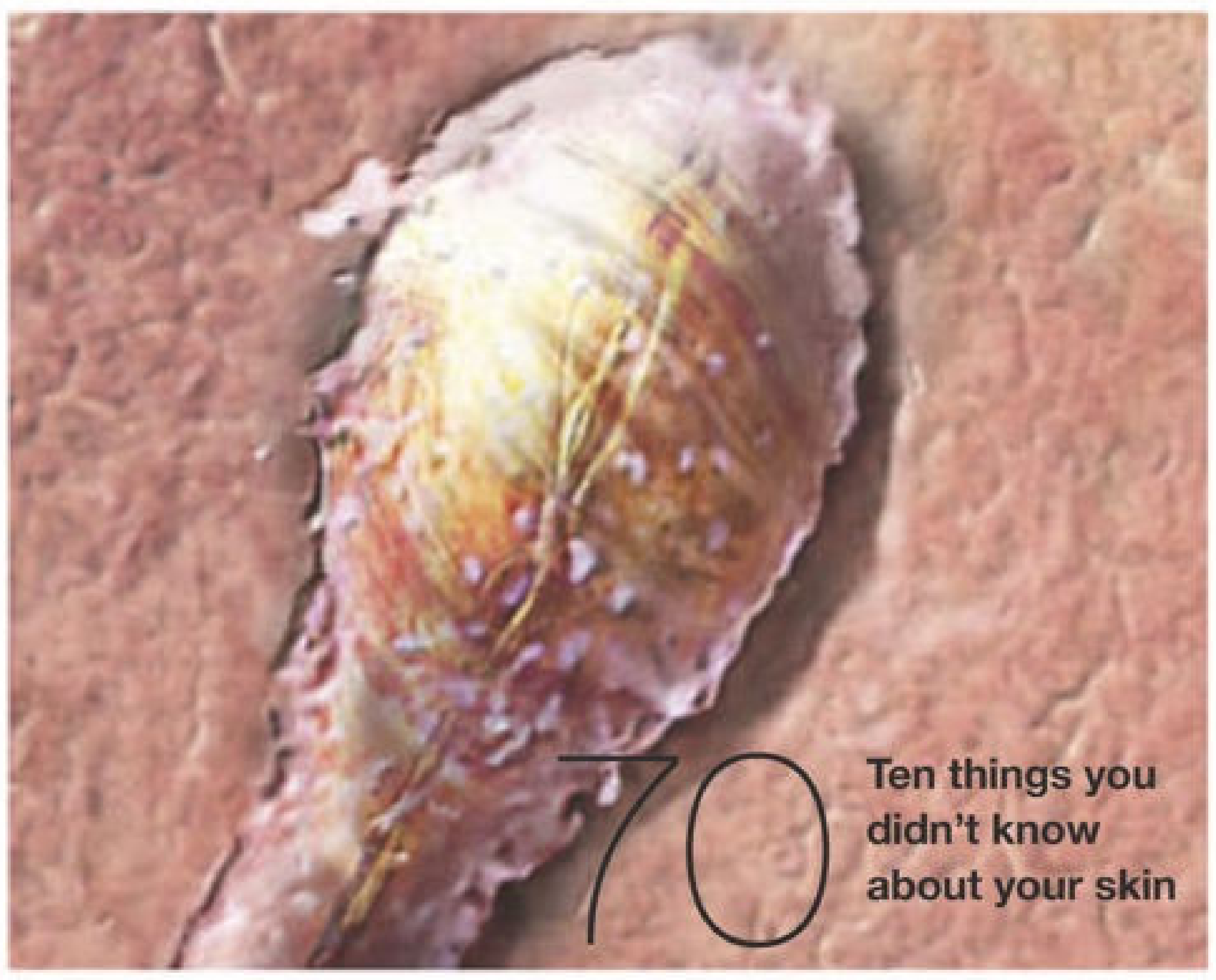

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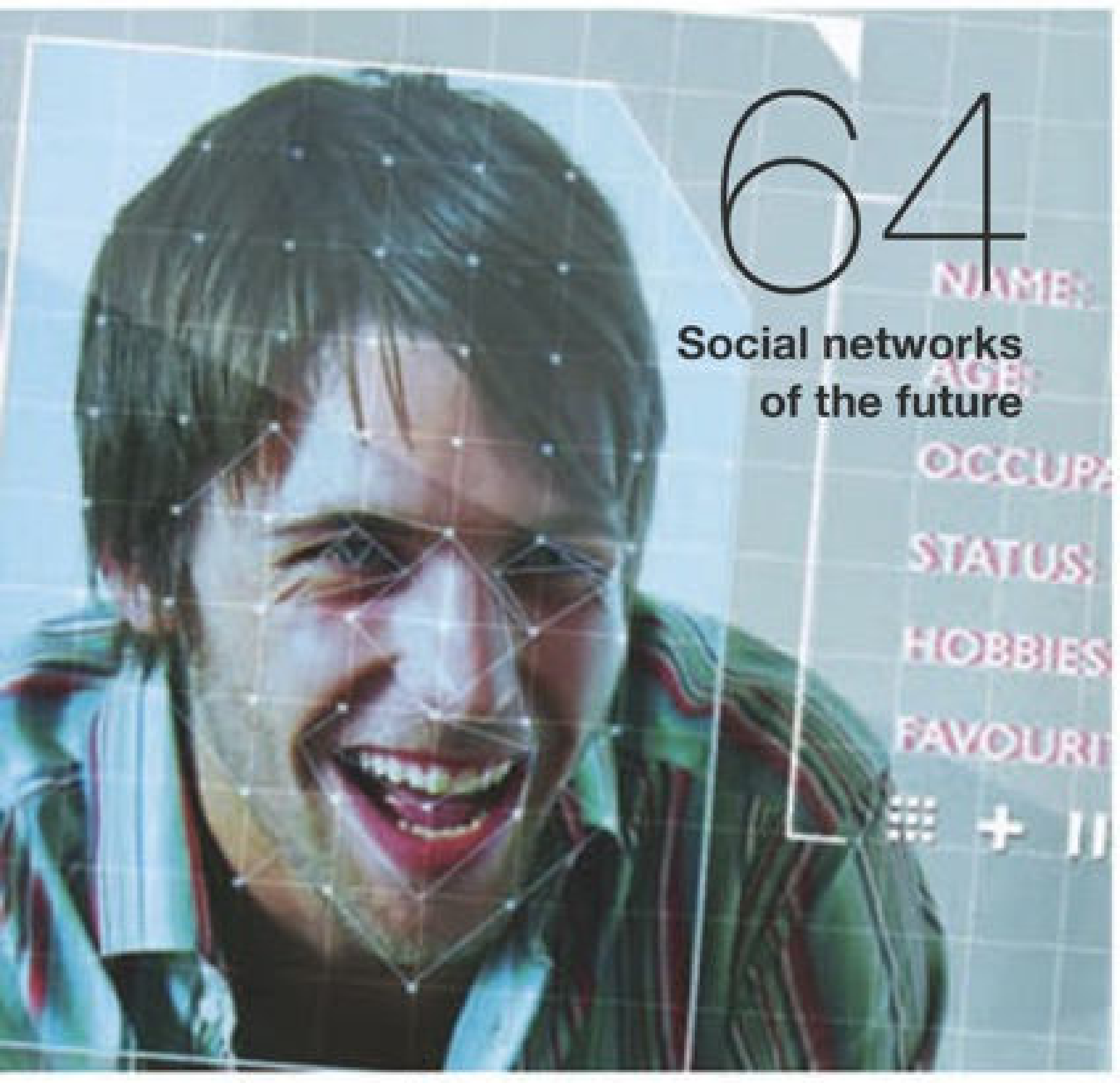

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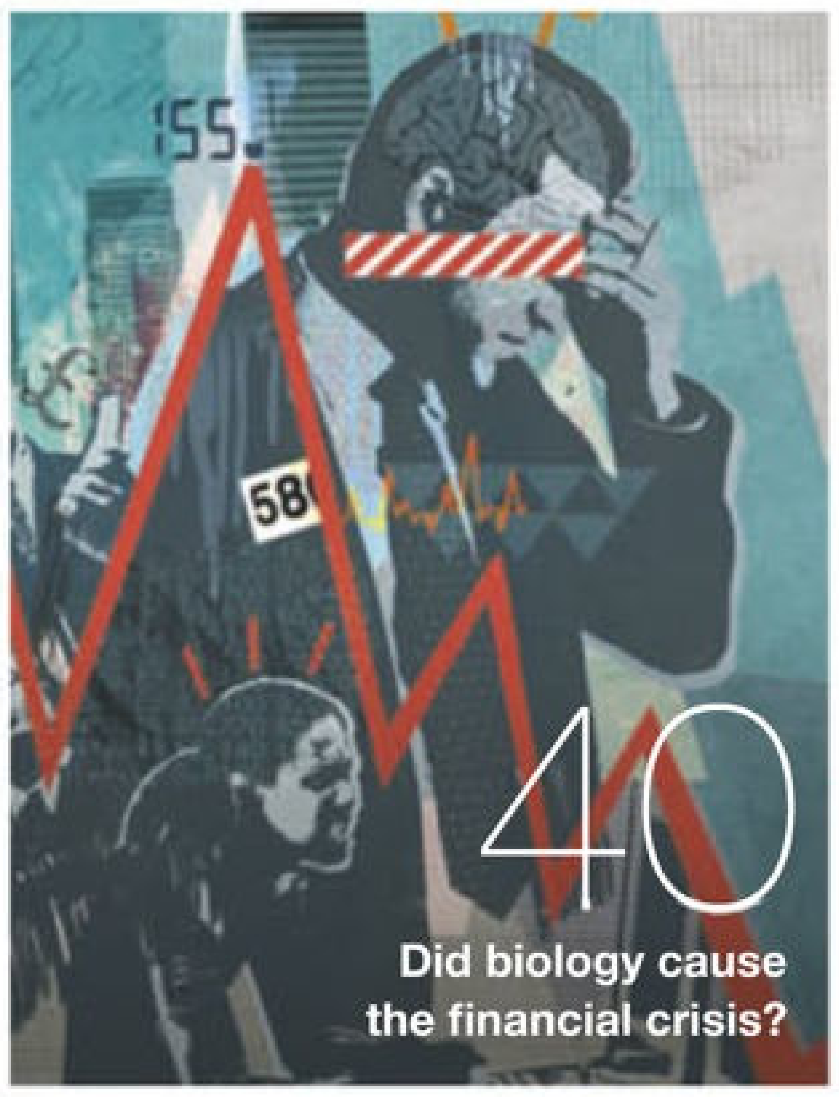

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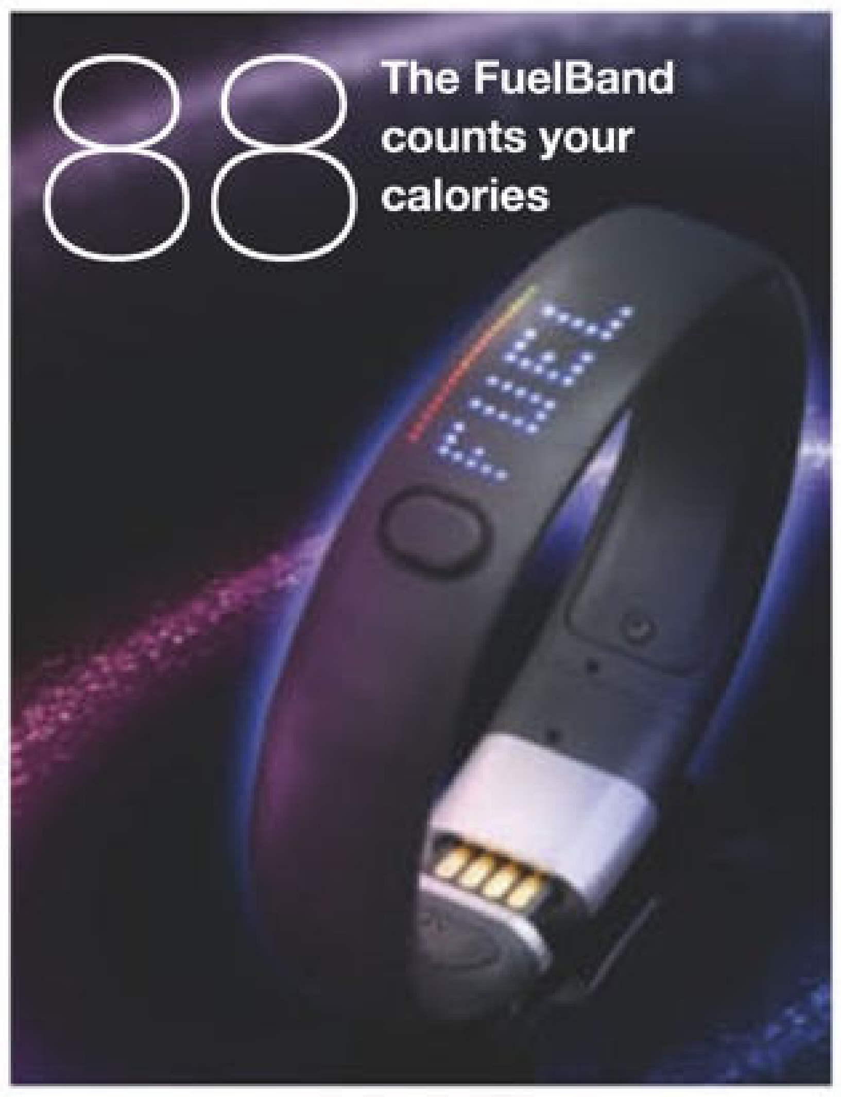

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On thin ice

It may look like a scene from some bizarre alien world, but this is in fact the space between two layers of ice on top of a river. To capture it, photographer Yuri Ovchinnikov climbed beneath the icy surface of Tianuksa River in Leningradskaya Oblast, near St Petersburg, Russia. The two layers of ice are separated by half a metre, the gap filled with unusual formations.

According to Professor David Sugden, an expert in glacial and polar geomorphology at the University of Edinburgh, this icy cavern is actually quite a common phenomenon. In the autumn, when temperatures fall below zero degrees, the river's surface freezes over. This frozen layer rests on the riverbanks and rocks while the water below continues to flow.

"Over winter the cold freezes more and more water draining into the river and this causes a drop in the water level," says Sugden. "This forms two layers of frozen water. The cold air in the space between creates these interesting ice formations. To form the ice columns, water might have been dripping from the surface ice, rather like stalactites."

CATERS NEWS

Ant assassins

These weaver ants (*Oecophylla smaragdina*) will not be able to eat their victim – they are unable to swallow chunks of fly. Instead they'll carry the fly to the nest, where it will provide a protein-rich meal for larvae, which can ingest other insects. The ants themselves drink sugary water released by scale insects, bugs that draw sap from plants.

"Weaver ants are aggressive and highly territorial," says Dr Stefanie Kautz, an ant expert at the Field Museum of Natural History in Chicago. "They're often helpful in orchards where they will drive other insects away."

The ants get their name from their habit of sticking leaves together to form their nests. "They carry larvae from the nest and hold them up to leaves. The larvae then spin silk, which can stick two leaves together," says Kautz. If the leaves are too distant for a single ant worker to reach, chains of ants will be formed to draw the leaves together. Studying how the ants communicate to form these worker chains may help scientists develop new models of complex behaviour.

UDA DENNIE/SOLENT NEWS

Full metal jacket

This 9mm bullet looks almost like an asteroid as it hurtles through a sheet of plastic glass. "The bullet's comet-like tail shows that it has skid," says ballistic forensics expert Dr Christopher Shepherd from the University of Kent. "This tells me the gun wasn't fired perpendicular to the glass. With closer analysis you could get an idea of the angle it was fired from."

Look closely and you can also see that the 'skid' is made up of a series of fine lines, which Shepherd says would be another useful clue at a crime scene had a bullet been shot into a similarly dense material. "As a bullet travels down the barrel it picks up rifling marks, and they create a kind of negative on the glass. If the bullet is missing, this can help narrow down the type of ammunition fired, and the kind of gun it was fired from."

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Summer 2012

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Why we consume too much fructose, p22

Viruses to power your phone

Microbes could produce electricity from your footsteps or heartbeat

Viruses have a bad reputation – they are, after all, responsible for colds and chickenpox. But for the first time, a genetically engineered virus has been turned into a tiny electricity generator. It could be used to power gadgets like mobile phones or medical devices. “We could implant a virus-based power generator into someone’s body and use their heartbeat as a power source for devices such as pacemakers and hearing aids,” says Professor Seung-Wuk Lee, a bioengineer at the University of California, Berkeley, who worked on the project.

The researchers used the virus M13, which only attacks bacteria and is harmless to humans. It produces power when it’s moved via the piezoelectric effect, which converts mechanical energy into electricity.

Piezoelectric materials are nothing new. They are already used in a variety of household objects, from gas hobs to inkjet printers. However, the best performing variants contain lead, which is toxic and unsuitable for use in the body. “The M13 virus is bio-compatible,” says Prof Lee.

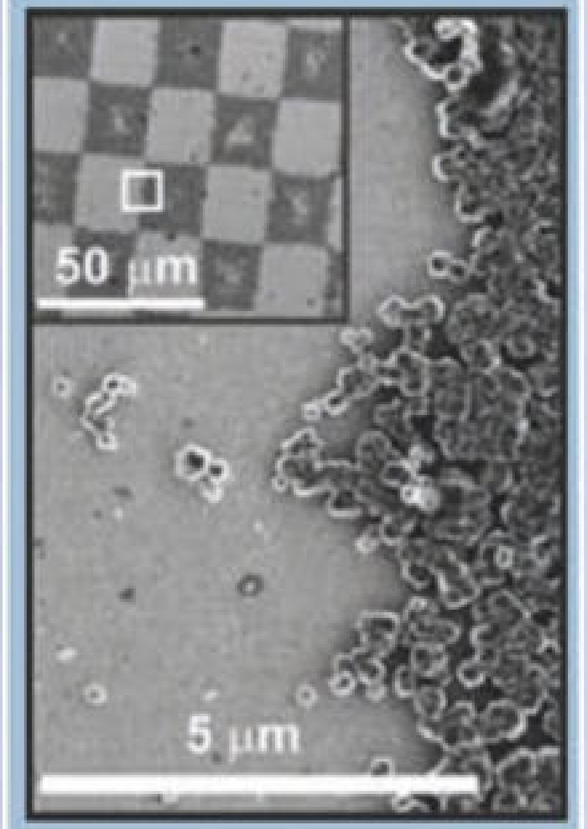
The rod-shaped virus ‘self-assembles’ into a film, and stacking these films increases the piezoelectric effect. M13 is coated with around 2,700 rod-shaped proteins, each of which is positively charged at one end and negatively charged at the other. When the virus is compressed, the proteins shift about so the charges no longer balance along the virus’s length, creating a current. To enhance its electricity-generating abilities, the researchers at UC Berkeley and the Lawrence Berkeley National Laboratory genetically engineered the virus, adding negative amino acids to the negative ends of the proteins.

In trials, applying pressure to a virus generator measuring just 1cm^2 generated six nanoamperes of current – enough to light up a small LCD. “Our work is a promising first step towards producing low-power electronic devices, such as environmental sensors, using viruses within 5-10 years,” says Lee.

Personalised power generators in our shoes are further off, requiring at least a 100-fold and possibly a 1,000-fold increase in power.

This LCD is powered entirely by a virus

Bacterial bytes



Iron-eating bacteria: the future of hard drives

Viruses aren’t the only microbes being used in electronics. A research team at the University of Leeds has borrowed a technique from bacteria in their quest for a better hard drive.

Magnetospirillum bacteria eat iron, which interacts with a protein inside their body to produce magnetic nanoparticles. They use these particles to navigate along the Earth’s magnetic field lines. Inspired by this, the researchers used the same protein to grow their own nanomagnets.

Because every single bit of data on a hard drive is stored in a tiny magnetic region, these nanomagnets could become the basis of a new high-capacity hard drive. Using smaller magnets would allow even more data to be squeezed onto a disk.

SHUTTERSTOCK, BERKELEY LAB

The Sun-powered plane Solar Impulse prepares to take off from Switzerland on its journey to Morocco on 24 May 2012

Solar-winged wonder

With a wingspan of 60m (200ft), the Sun-powered Solar Impulse is an imposing sight. It recently became the first aircraft to complete an intercontinental flight without using any fuel.

Solar Impulse's wings, which are longer than those on many commercial aircraft, house more than 12,000 solar panels. These soak up the sunlight required to power electric motors that turn the propellers. The panels also charge lithium polymer batteries, which enable Solar Impulse to remain airborne at night.

Solar Impulse, which has been in development since 2003, has already been in the record books for some time. In 2010, Swiss businessman, pilot and co-founder of the Solar Impulse project André Borschberg flew for 26 hours, 10 minutes and 19 seconds non-stop in the aircraft, setting a new record for the longest flight in a manned solar-powered plane.

For the latest record-setting mission, successfully completed on 6 June, Borschberg was joined at the controls by his Solar Impulse partner, psychiatrist and balloonist Bertrand Piccard. Between them the pair flew the plane from Payerne, Switzerland to Madrid in Spain, and then – after a few days' wait for favourable weather conditions – on to Rabat, Morocco, in a journey that took 19 hours and eight minutes.

The maximum altitude reached during the final leg of the journey was 8,229m (27,000 feet), and average groundspeed was 51.8km/h. The trip was a rehearsal for an attempt to fly round the world, which is planned for 2014.

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MONTH IN NUMBERS

11

million-year-old teeth found in Spain could be the earliest trace of the giant panda's evolutionary line. The teeth belonged to a small bear of the species *Agriarctos beatrix*

42,000

years is the age of flutes found in a cave in Germany, making them the oldest-known musical instruments. The flutes were fashioned out of bird bone and mammoth ivory

1

extra year of education appears to cut the risk of dying aged 40-70 significantly, according to new research based on the lives of Swedes who went to school between 1949 and 1962

Potentially Hazardous Asteroids in low-inclination orbits are more likely to hit us

Telescope counts hazardous asteroids

NASA's estimate reveals just how many dangerous space rocks we haven't yet found

Around 4,700 potentially hazardous asteroids (PHAs) surround Earth, according to new results from NASA's WISE space telescope.

An asteroid is classed as 'potentially hazardous' if its orbit brings it within eight million kilometres (five million miles) of Earth, and it's 330 feet or more across. That's large enough to pass through Earth's atmosphere and devastate the region where it lands, or cause a tsunami if it hits the sea.

Astronomers used WISE to look at a sample of PHAs, which allowed them to estimate the total number. If correct, it means that just 20-30 per cent of potentially hazardous asteroids have been located. "We've many more to find, and it will take a concerted effort during the next couple of decades to find all of them that could do serious damage or be a mission destination," says Lindley Johnson of NASA's Near-Earth Object Observation Program.

The study also found that twice as many PHAs as previously thought have so-called 'lower-inclination' orbits. Since these orbits are more closely aligned with that of Earth, they're more likely to hit us. On the other hand, this means there are more potential destinations for future robotic spacecraft or manned missions, which could prove useful – President Obama having directed NASA to land astronauts on a space rock by 2025.

PHAs in lower-inclination orbits also appear to be brighter and smaller than other near-Earth asteroids. This means they're more likely to be either metallic or made of stone. Knowing the composition will help scientists work out how quickly the rocks would burn up in Earth's atmosphere, and so how great a threat they'd pose.

WISE detected the infrared light, or heat, given off by asteroids so it was able to spot both light and dark objects. The sensitivity of the WISE detectors limited its ability to spot small, more distant, asteroids. So a dedicated asteroid-hunting mission called the Near-Earth Object Camera, or NEOCam has been proposed, which would give us a few decades' warning of a major impact.

GOOD NEWS

A nicotine 'vaccine' could be at hand. US company Selecta Biosciences has created nanoparticles that trick the body's immune system into making antibodies that bind to nicotine molecules, making them too big to enter the brain.

Mice lacking just one gene have bigger brains. Without the Snf2l gene, mice brains were 35 per cent larger than normal, Canadian scientists found. The research could help improve treatments for stroke victims.

Looking away reduces the pain of an injection, say scientists in Germany who found electrical stimuli were more painful when volunteers watched a video of a needle pricking a hand.

BAD NEWS

A gene linked to good memory could increase your chances of developing post-traumatic stress disorder (PTSD). In Swiss tests, volunteers with a variant of the PRKCA gene recalled more detail from disturbing images. Survivors of the 1994 Rwandan genocide with the same variant were more likely to suffer from PTSD.

Another distant exoplanet has been spotted by NASA's Kepler mission – but it's disintegrating. The planet is baked by temperatures of around 1,900°C and has a long tail of its own debris following it.

A new study suggests that in some parts of the Amazon, up to 40 per cent of mammal species will not be able to move quickly enough to avoid destruction of their habitat by climate change.

INSIGHT

Human textile

What is it?
A new kind of medical graft created by weaving together material produced by human cells in a large braiding machine. The resulting 'textile' can be used to patch up damaged blood vessels or the heart.

How is this stuff made?
Human skin cells are grown in a flask and encouraged to produce extra 'cellular matrix', a web of proteins that spans the space between cells in the body. These sheets are then sliced into thin ribbons, which are woven into cylindrical vessels.

Where did the idea come from?
San Francisco-based company Cytograft Tissue Engineering has already developed blood vessel replacements using sheets of cultured connective tissue rolled into cylinders. But cylinders take months to manufacture, increasing costs. Each rolled vessel costs up to $10,000 (£6,400).

Why weave the material?
According to Dr Nicolas L'Heureux, Cytograft's Chief Scientific Officer: "Weaving produces textiles that are not only stronger, but also require a third of the time to make as rolled cylinders and cost a third as much. Textile technologies are 200 years old, and they can solve an enormous number of problems."

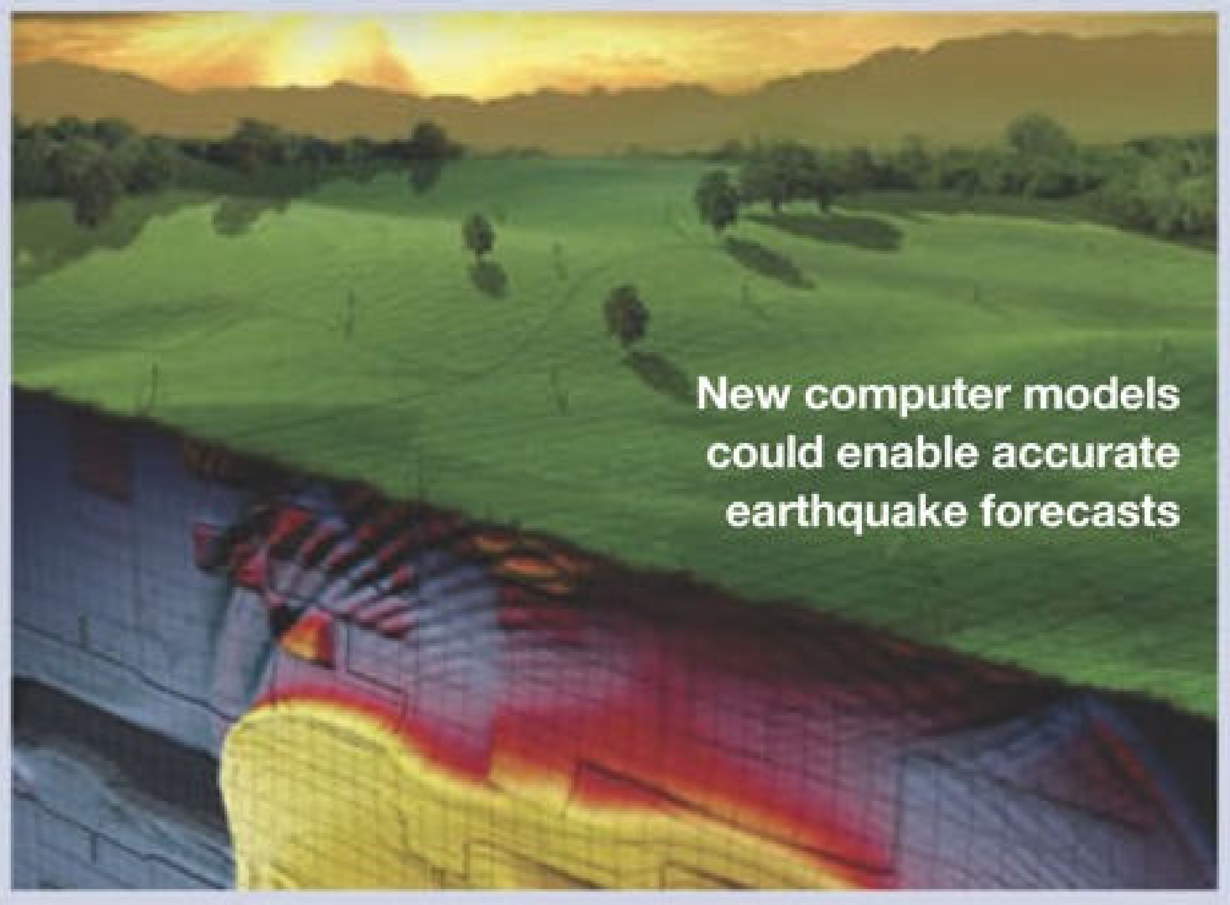
When will it be used in hospitals?
Cytograft is going to conduct a human clinical trial with the rolled vessels next year. The woven versions are still in animal trials.

The human cells are woven by machine

CYTOGRAFT, LIZ BRADFORD, ILLUSTRATION BY ACUTE GRAPHICS

ROUND UP

This month's top science stories from around the globe



New computer models could enable accurate earthquake forecasts

SEISMOLOGY

Quake, rattle and roll

A computer model is being used to simulate the behaviour of the most studied 25km (16 miles) of fault line in the world. The study could lead to the Holy Grail of seismology: accurate earthquake predictions. Researchers at the California Institute of Technology used 30 years' worth of observations of the Parkfield segment of the San Andreas Fault as well as seismological theory to create their model. The simulated earthquakes look similar to the real thing and occur at the same frequency.

HEALTH

How aspirin blocks cancer

Zebrafish have helped reveal how aspirin can protect against cancer. Previous studies have shown that white blood cells, part of our immune system, help cancers to grow by delivering growth chemicals. Researchers at the universities of Bristol and Sheffield used the translucent fish to watch how white blood cells interact with early cancer cell formation. They found that aspirin's tumour-blocking ability is due at least in part to the fact that it starves the cancer cells of these chemicals.

HUMAN BIOLOGY

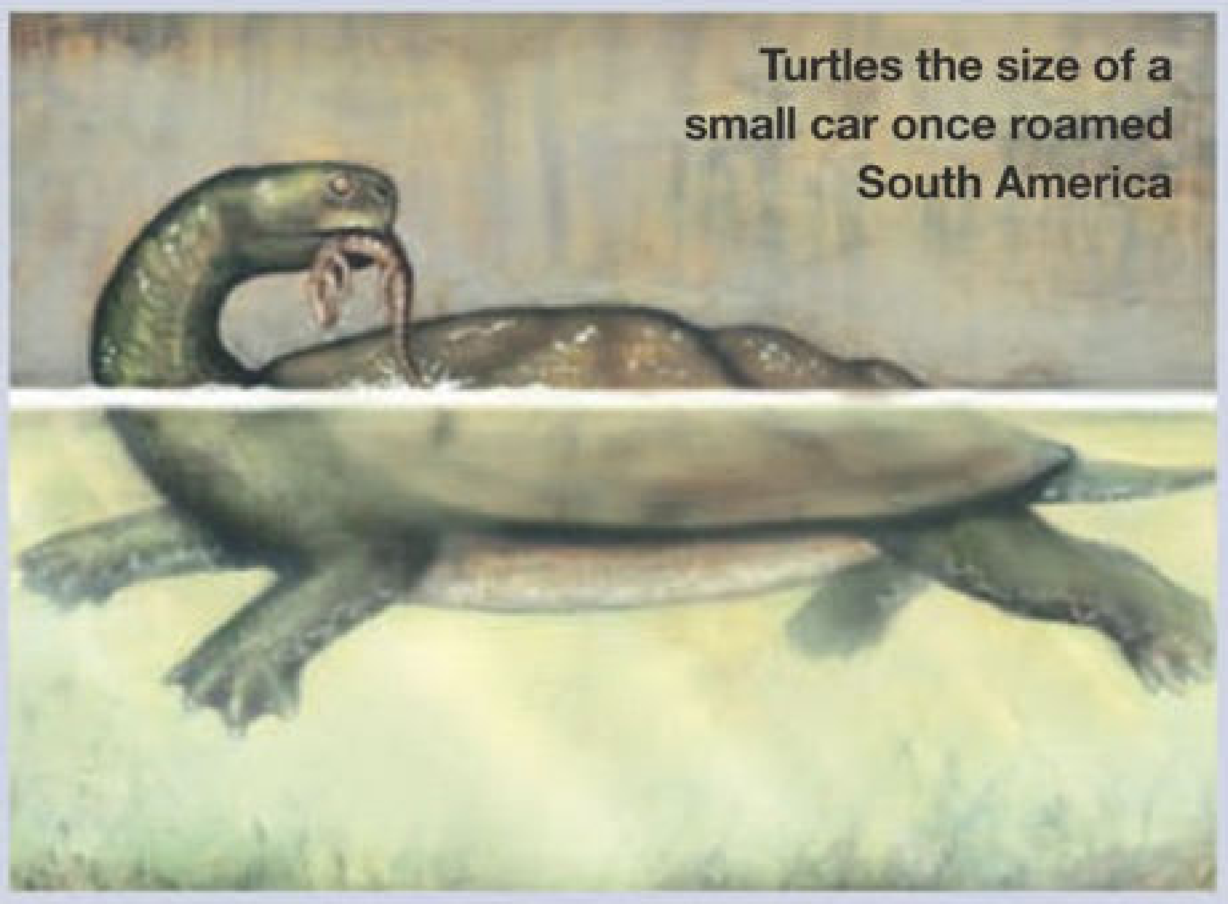
Sweat reveals your age

It seems that we have an uncanny ability to tell how old someone is from the way they smell. Volunteers from three age groups – 20-30, 45-55 and 75-95 – slept with sweat-gathering pads under their arms for five nights. When these were sniffed at the Monell Chemical Senses Center in Philadelphia, participants in the study were able to tell which of the age groups each sweat donor came from. Further research will now identify which chemicals in human sweat make age identifiable.

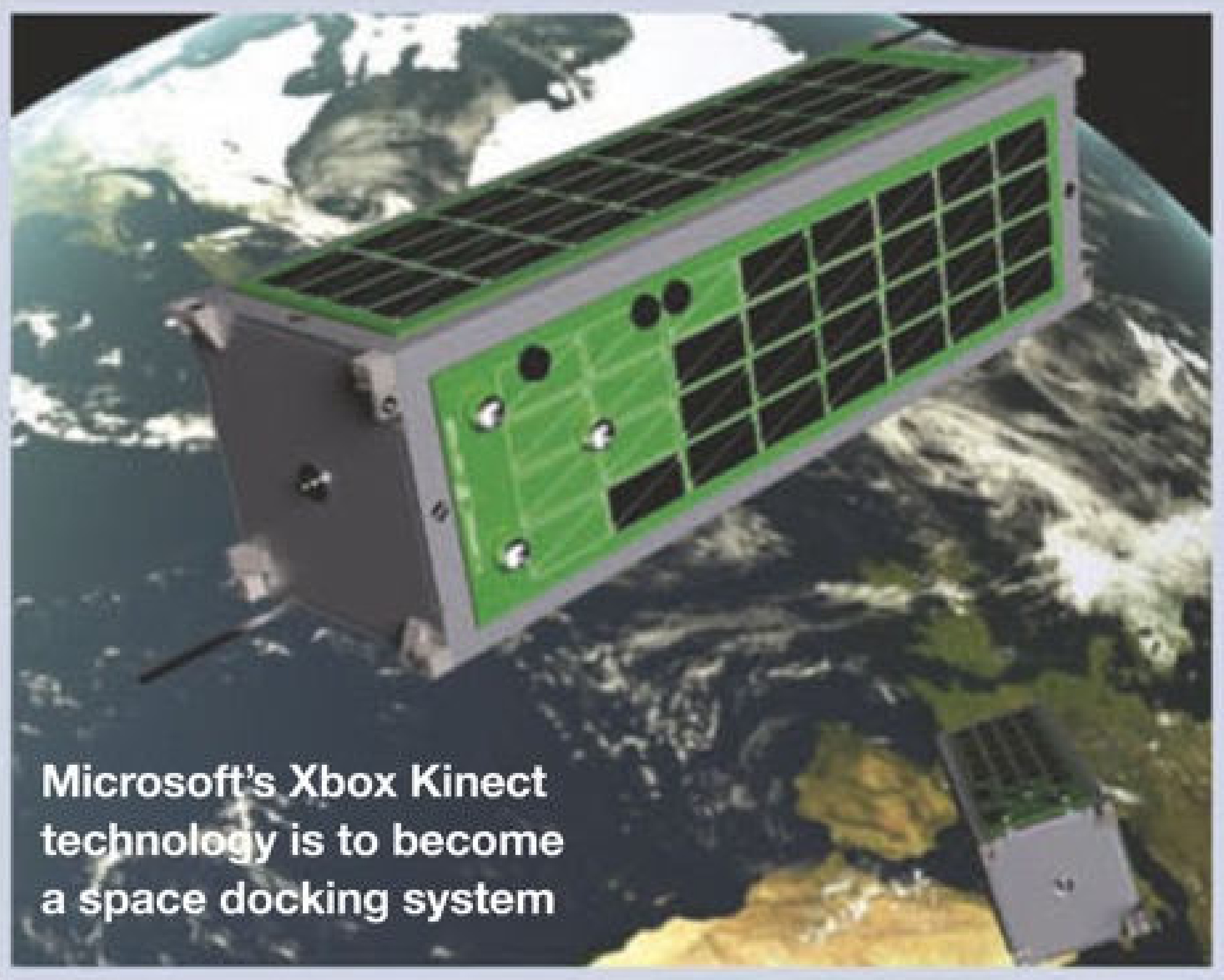
PALEONTOLOGY

Ancient turtle was a giant

A turtle the size of a Smart car lived in what is now Colombia 60 million years ago. Fossils of the creature, discovered by palaeontologists at North Carolina State University, show it had powerful jaws that would have enabled it to dine on smaller turtles or even crocodiles. *Carbonemys cofrinii* appeared five million years after the dinosaurs died out, at a time when giant varieties of many reptiles lived in South America thanks to the presence of fewer predators and an abundant supply of food.



Turtles the size of a small car once roamed South America



Microsoft's Xbox Kinect technology is to become a space docking system

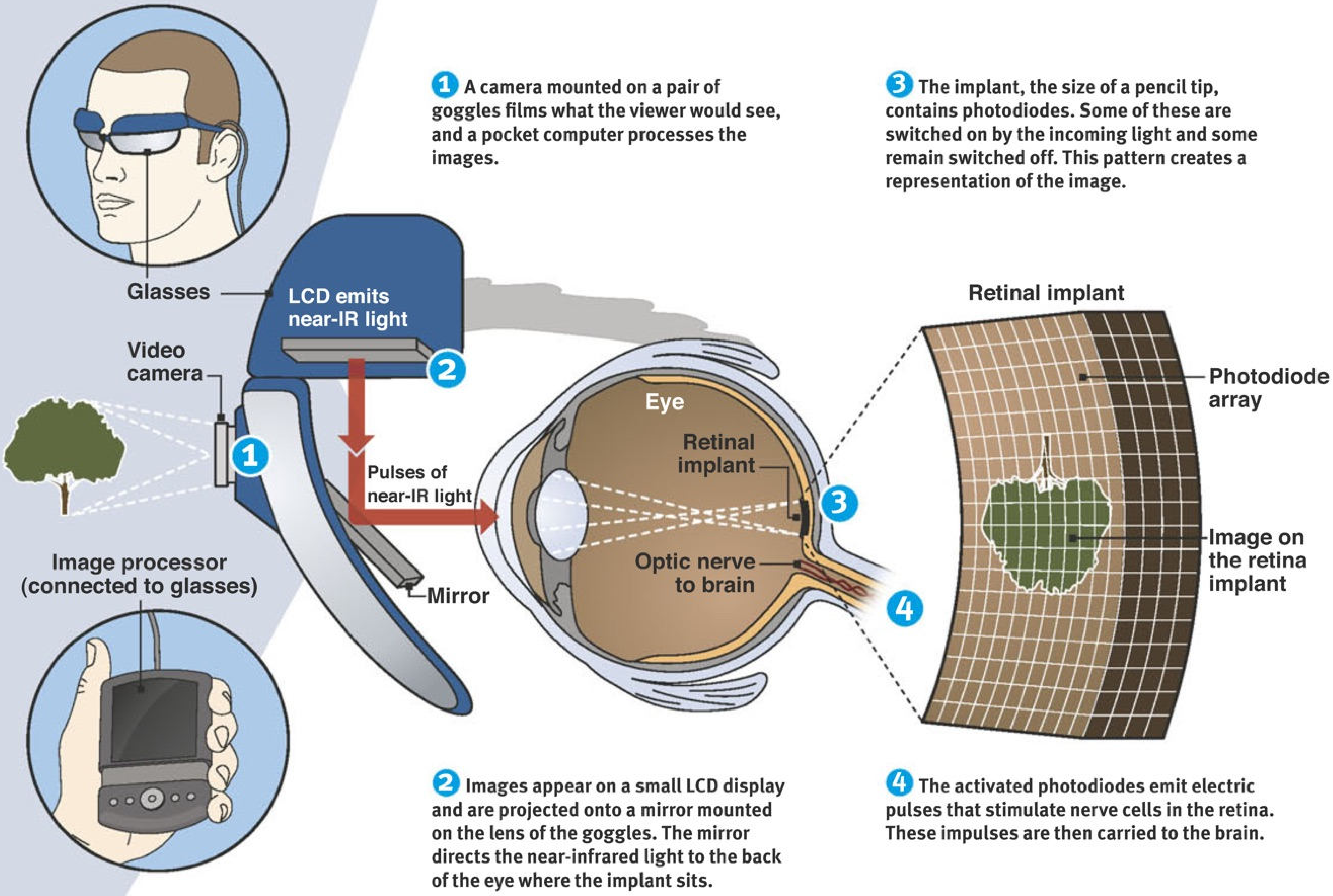
SPACE

Kinect goes into space

Parts from an Xbox Kinect are being incorporated into tiny British satellites to provide a cheap docking system. Docking systems are usually the preserve of big budget missions, but engineers at the University of Surrey and Surrey Satellite Technology are incorporating the gaming technology in their pair of STRaND-2 satellites to provide them with 3D spatial awareness. The technology will allow nanosatellites to be used as building blocks for more sophisticated structures.

THE NEXT-GENERATION BIONIC EYE

Receptors implanted in the back of the eye offer new hope to the blind



① A camera mounted on a pair of goggles films what the viewer would see, and a pocket computer processes the images.

② Images appear on a small LCD display and are projected onto a mirror mounted on the lens of the goggles. The mirror directs the near-infrared light to the back of the eye where the implant sits.

③ The implant, the size of a pencil tip, contains photodiodes. Some of these are switched on by the incoming light and some remain switched off. This pattern creates a representation of the image.

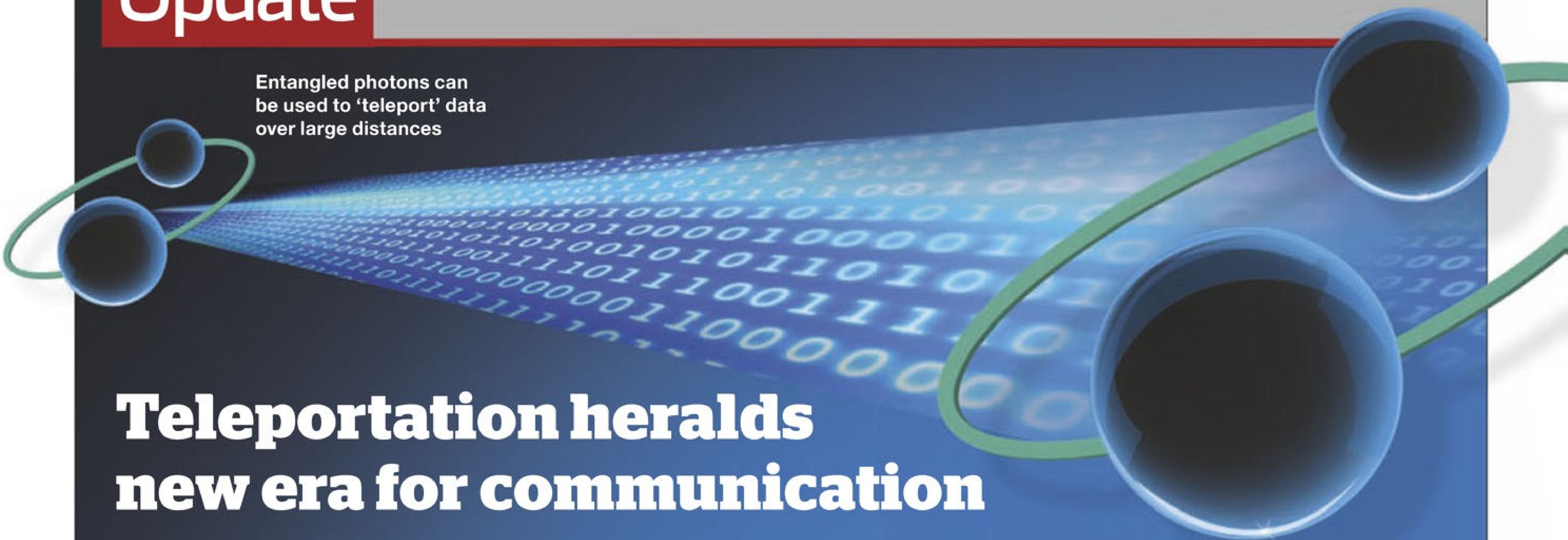
④ The activated photodiodes emit electric pulses that stimulate nerve cells in the retina. These impulses are then carried to the brain.

Scientists at Stanford University School of Medicine in the US have invented an implant that could help the blind to see. The implant, which sits at the back of the eye, would help patients suffering from diseases in which photoreceptor cells in the retina slowly degenerate. It acts as an artificial retina, taking in information from the outside world and converting it into electrical signals which are fed to the brain.

Several other 'bionic eye' systems have been developed previously, all of which have required coils, cables or antennae to be embedded in the eye to deliver power and information to the implant. But in this new system, near-infrared light is beamed to an implant made up of light-sensitive diodes. These convert the light into an electric current that's fed to the existing retinal nerves, reducing the amount of electronics that need to be embedded in the eye.

"To make this work, we have to deliver a lot more light than normal vision would require," says Associate Professor Daniel Palanker at Stanford. "If we used visible light, it would be painfully bright." Near-infrared (near-IR) light was the answer: it isn't visible to the naked eye, but it can be detected by the implanted diodes.

So far, the implant has only been tested in rats. But it has the potential to treat both age-related macular degeneration, the leading cause of blindness in the UK, and retinitis pigmentosa, which affects 1.5 million people worldwide. In both conditions, the retina's photoreceptor cells degenerate but the nerve cells in the retina, on which the 'bionic' implant relies, remain intact.



Entangled photons can be used to 'teleport' data over large distances

Teleportation heralds new era for communication

The distance record for teleportation has been broken, bringing us closer to an ultra-secure way of transmitting data over large distances.

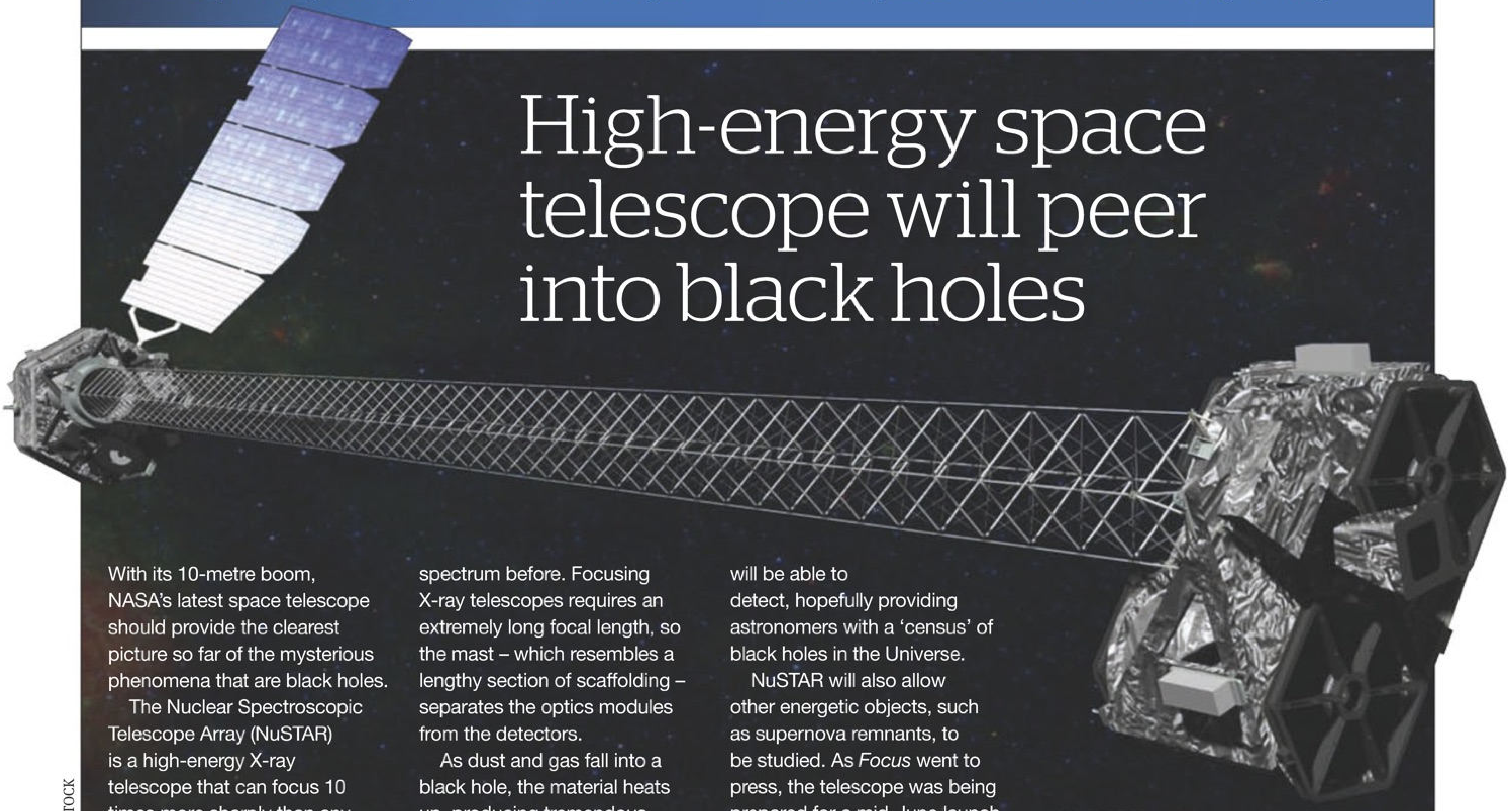
In *Star Trek*, the crew were teleported onto the surfaces of alien planets. And for some time now, physicists have been able to achieve teleportation – not by physically moving an object, but by teleporting the information that describes it. A similar object at the receiving end can then take on the first object's identity. In the strange world of quantum physics, this is possible because of a phenomenon called entanglement, whereby two subatomic particles can be made to mimic each other's behaviour – even if one of those particles is on the Moon.

Physicists at the University of Science and Technology of China have managed to teleport the quantum state of photons (particles of light) 97km, smashing the previous record of 16km. It's an important breakthrough as changes to the quantum states of the entangled particles can be used to transfer data, just as changes to the states of bits – 1 or 0 – can be used to transfer data in standard networks.

In quantum communication, no data is physically transferred between points A and B – so in theory, the data is impossible to intercept. Sending photons accurately over long distances has proved difficult – they're easily disentangled by air turbulence, for instance – but now the Chinese team has beaten its own record, using a brighter laser that produces more pairs of entangled photons.

This method could one day be used to transmit data securely. "The techniques developed in this experiment can be directly transferred to satellites," says Professor Yuao Chen, who was involved with the research. "With the help of a satellite, it could be possible to achieve distances of a few thousand kilometres." A quantum internet would then develop if several nodes started communicating in this way.

High-energy space telescope will peer into black holes



With its 10-metre boom, NASA's latest space telescope should provide the clearest picture so far of the mysterious phenomena that are black holes.

The Nuclear Spectroscopic Telescope Array (NuSTAR) is a high-energy X-ray telescope that can focus 10 times more sharply than any telescope that's studied this part of the electromagnetic spectrum before. Focusing X-ray telescopes requires an extremely long focal length, so the mast – which resembles a lengthy section of scaffolding – separates the optics modules from the detectors.

As dust and gas fall into a black hole, the material heats up, producing tremendous amounts of energy and radiating X-rays. It's these that NuSTAR will be able to detect, hopefully providing astronomers with a 'census' of black holes in the Universe.

NuSTAR will also allow other energetic objects, such as supernova remnants, to be studied. As *Focus* went to press, the telescope was being prepared for a mid-June launch from the Marshall Islands in the Pacific Ocean.

NuSTAR's mast gives it a longer focal length

NASA, THINKSTOCK

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THE BURNING QUESTION

Professor David Kennedy is Director of the Brain, Performance and Nutrition Research Centre at Northumbria University.

With David Kennedy

Is our diet reducing our intelligence?

Hippocrates, the father of modern medicine, was the first person to acknowledge that the food we eat has a direct effect on our health. Now, over 2,000 years after his death, we're beginning to understand how right he was.

In a new study carried out at the University of California, Los Angeles, rats fed a high-fructose diet for just six weeks were less able to learn and retain information – finding it tougher to negotiate a maze with just one exit. The rats had been fed high-fructose corn oil, a ubiquitous ingredient in processed drinks and foods churned out by the food industry, particularly in the US.

This is perhaps one of the most direct demonstrations that a ubiquitous foodstuff has the potential to affect the way we think. Fructose is the sugar that occurs naturally in fruit and is the favoured sweetener of the food and drink industry worldwide. Our consumption of it has risen exponentially from the modest levels associated with seasonal fruit to an average yearly per capita consumption in the US of more than 45kg of refined sugar, over half of which is fructose. The rest of the world is not far behind.

Fructose is a sugar found in fruit and processed foods – too much can have a detrimental effect on your brain power

Fructose is problematic because, unlike glucose, its consumption doesn't elicit the body's appropriate hormonal response to eating. It actually suppresses the effect of insulin and the brain chemicals that signal we are full and no longer hungry.

And therein lies the problem. Insulin affects the brain by controlling the blood levels of its primary fuel, glucose. Insulin receptors are also richly distributed throughout some areas of the brain, including those associated with regulating food intake and cognitive function.

A quick scan through the research journals shows that the latest study isn't on its own in pointing a finger at fructose. At the end of last year, Dr Xingwang Ye and colleagues from Tufts University in Boston reported in the British Journal of Nutrition that the level of habitual sugar intake in non-diabetic participants aged over 45 was inversely related to memory and cognitive performance. And in March and April this year a series of separate studies showed that insulin resistance is associated with greater cognitive decline and reduced brain volume in non-diabetic older people.

> *"Rats fed a high-fructose diet were less able to retain information"*

Pretty much all of the evidence in this area relates to older adults – whether we might see the same effects in younger people is an open question, since high levels of fructose are unlikely to have detrimental effects in the short term. Even the six weeks of fructose consumption that damaged the UCLA rats' brains would equate to several years in human terms.

Fructose isn't the only problematic component in our contemporary diet. There are plenty of studies showing that consuming high levels of 'bad' saturated fats, found primarily as meat and dairy animal fats, and as a range of oils added to processed foods, also predispose us to poorer mental function later in life.

The UCLA research did offer one crumb of comfort. When fed a slightly healthier diet with more omega-3 fatty acids, the effect of fructose on the rats' brains was reduced. There's also lots of research showing that a diet closer to that enjoyed by our ancestors in evolutionary terms, for instance the so called 'Mediterranean diet' typified by lots of natural fruit, vegetables and legumes, can protect against natural cognitive decline as we get older.

So if you hope to retain your intelligence into old age, you could do worse than follow Hippocrates's adage "let food be thy medicine".

WHAT DO YOU THINK?

Should there be regulation limiting the amount of fructose in our food?

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GETTY

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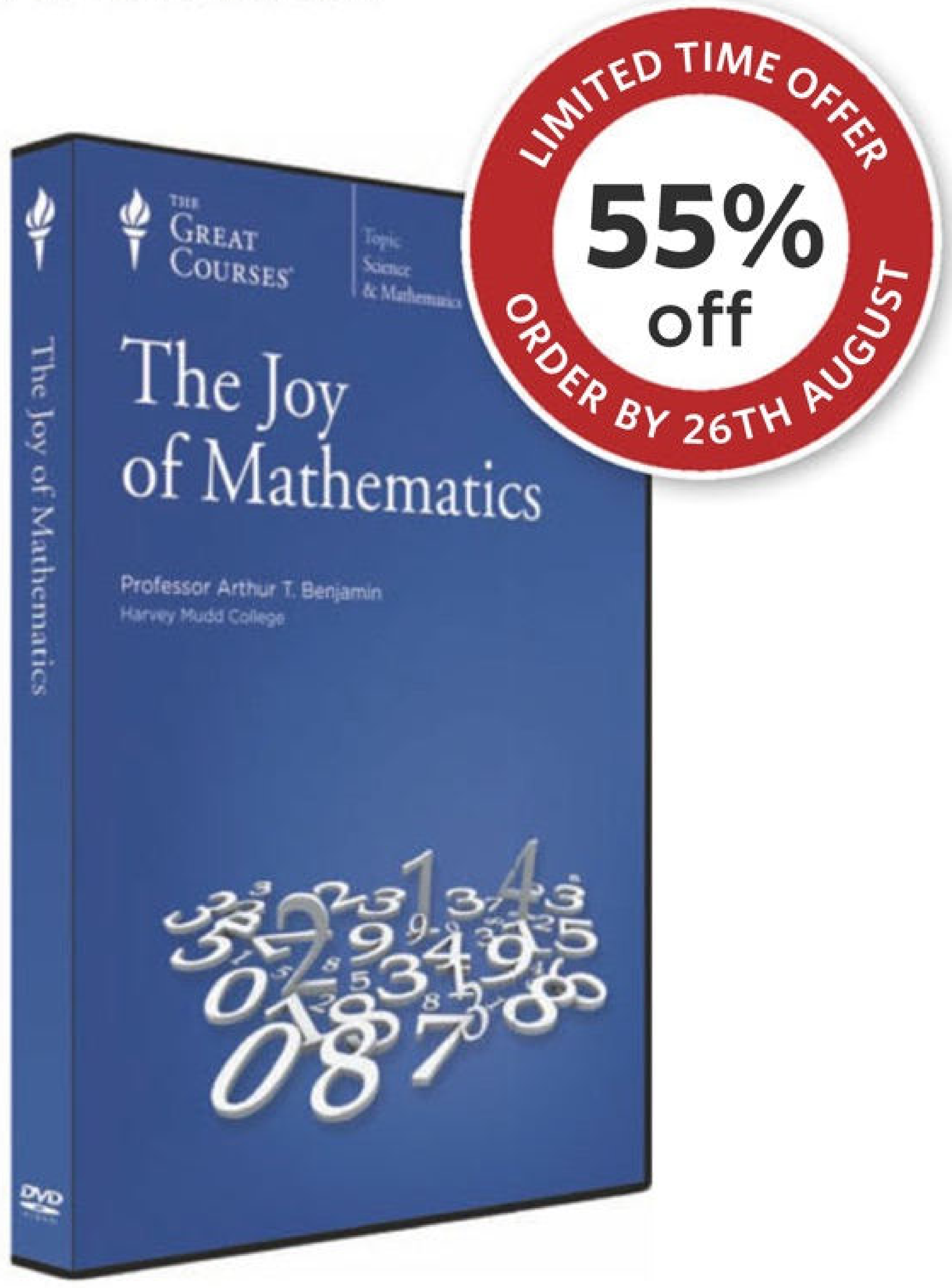

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The Analyst

Robert Matthews

From solar panels to low-energy lightbulbs, green technology came along too soon

The Sun may be high in the summer sky again, but it seems to be setting on green energy companies – especially those involved in solar power. Since last summer, some of the biggest names in the business have gone bust.

The dark clouds of the global financial crisis haven't been good for solar energy. Governments can no longer afford to hand out the hefty subsidies that have propped up so many green industries for so long. Politicians have also realised that voters would rather they focused on saving the economy than saving the planet.

But there's a less obvious reason for the collapse – and, oddly, one that bodes well for the future. It's that many of these companies found themselves massively undercut by high-tech, low-cost manufacturing outfits in Asia.

Anyone who knows anything about manufacturing could have seen that one coming. Sadly, that doesn't include most politicians. In their haste to appear like planet-saving superheroes, they handed out money to anyone with a business plan that included the word 'green'. If they'd just been a bit more measured in their response, they could have got everything built for a fraction of the cost. It only took Asian companies a few years to tool up – and only the most wild-eyed eco-nut thought we had less time than that to avoid Armageddon.

But the politicians made another classic blunder in their race to save the planet: they fell into the 'early adopter' trap, paying over the odds for technology that isn't up to the task. To be fair, though, a lot of us have fallen for that one. I'm confronted by an example every time I go out into the garage. I switch on the light and find myself instantly immersed in an eerie twilight.

> "Politicians handed out money to anyone with a business plan that included the word 'green'"

That's because a couple of years ago my partner decided to do her bit for the planet and swapped an old-fashioned light bulb for an energy-saving compact fluorescent light, or CFL. I don't doubt it uses far less energy than one of those old bulbs; the resulting savings may even pay for the bulb itself in the long run. But I also know that in the short run the CFL is useless. It takes 30 seconds to reach the illumination level of a glowing twig, by which time I've usually banged my head on some shelves and tripped over a bike.

The most irksome thing is that it's all so unnecessary – even when it was bought, it was clear that CFLs were heading for obsolescence. The CFL was already being outshone (in every sense) by the technology of the white LED. Far more efficient, cost-effective and instant, this is the ultimate light source, and it's already finding its way into our homes.

It's a similar story with solar power itself: truly revolutionary technology that can work even on overcast days is now starting to emerge. One example that comes to mind is the dye-sensitized cell (DSC), which mimics the ability of plants to turn sunlight into electric current. Over the last 30 years, the effectiveness of DSCs has soared, and now it's largely a matter of getting production costs down to the stage where they are competitive with conventional solar cells. If anyone can do this, it's the manufacturing geniuses of Asia – and they'll do it without a penny from us in subsidies.

So there's one thing to be said for the financial crisis: at least our politicians are no longer wasting our money on green technology that isn't fit for purpose.

SAVE THE ECONOMY NOT THE PLANET
GO GREEN

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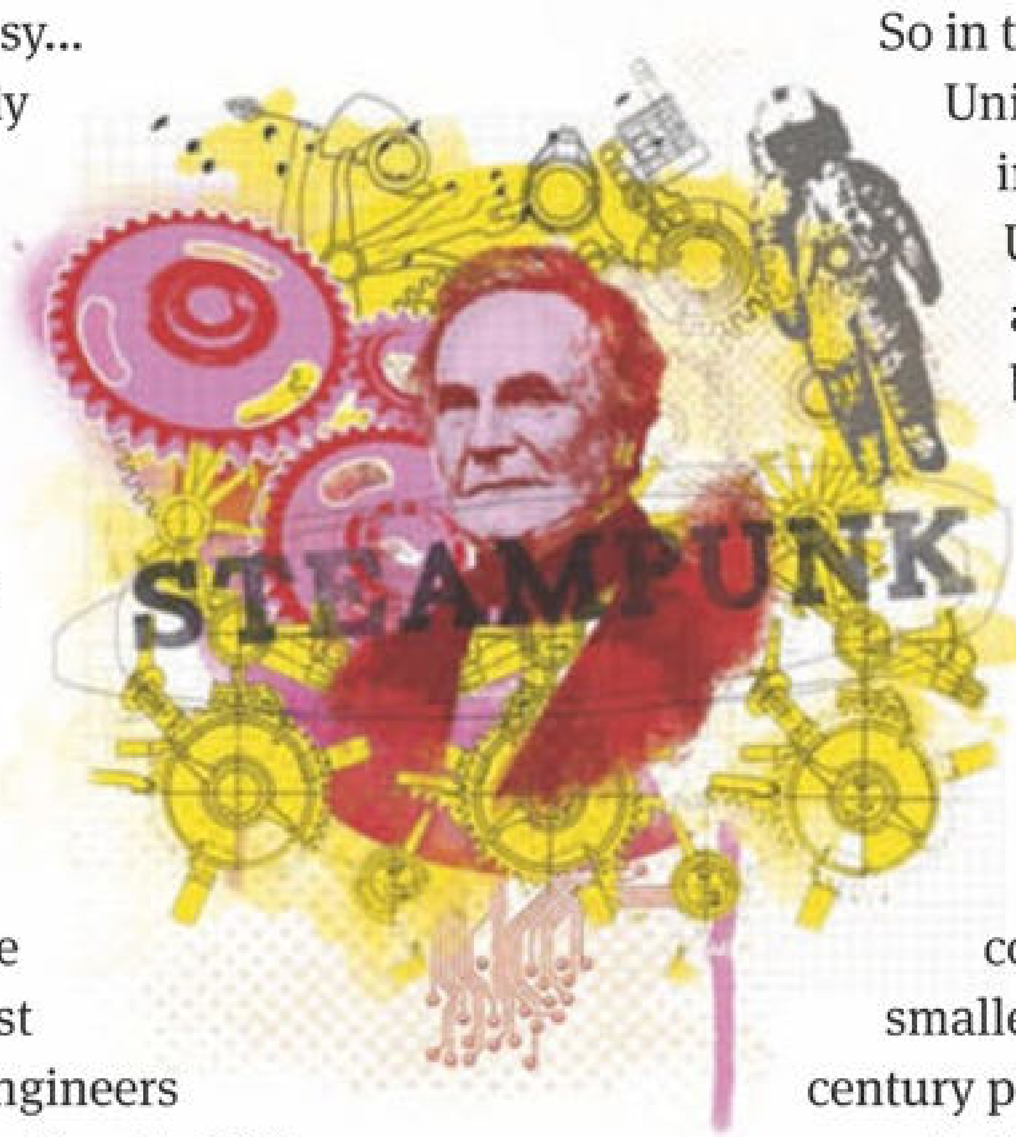
The Futurist
Stephen Baxter

How Victorian technology is making a comeback

Steampunk, a reimagining of 19th-century Jules Verne-era technologies like airships, clockwork automata and Babbage-engine artificial brains, is all the rage. You'll see its influence in books such as *The Difference Engine* by William Gibson and Bruce Sterling (1990), episodes of *Doctor Who* and movies like *The League Of Extraordinary Gentlemen* (2003) and *Sherlock Holmes* (2009 and 2011).

But it's all fantasy... or is it? Remarkably enough, modern engineers are turning to steampunk chic to develop systems that can cope with extreme environments such as nuclear plants or the depths of space.



Charles Babbage was one of the most forward-looking engineers of the 19th century. Born in 1791, he tried to automate the production of mathematical tables like logarithms, then compiled by hand and full of errors. His first 'difference engines' were computing machines based on clockwork and mechanical switches, similar in function to pocket calculators. He ran out of money before completing a prototype, but when such a machine was finally built by the Science Museum in 1991, its results were correct to 31 digits. Babbage's next-generation 'analytical engine' would even have been programmable, using punched cards as were then used to control looms.

Babbage's computers, with steam-driven pistons turning cogs and levers, were unwieldy and slow compared to modern electronic computers, which use arrays of transistors to process logic. But in recent years mechanical computing has begun to make a surprising comeback.

In some applications, such as the control systems of modern jet engines, extreme heat is a hazard for electronics. Above 250°C, thermally generated electrons will swamp a transistor's electronic control. Ionising radiation is also a hazard in environments like nuclear plants or space, because it creates spurious electrical charges in the materials it strikes, confusing the logic systems.

So in the 1990s, teams at the University of California in Berkeley and at the UK's Defence Evaluation and Research Agency began to experiment with mechanical logic circuits based on micro-electromechanical system (MEMS) technology. MEMS systems have components much smaller than their 19th-century predecessors but are still essentially mechanical, based on tiny levers and crossbars. And these mechanical circuits, while slower than their electronic counterparts, are also much more resistant to heat and radiation.

In 2010 a team in Cleveland, Ohio built a MEMS inverter. Inverters are an essential part of all logic circuits. They are usually made up of transistors and resistors, but the Cleveland team's inverter is based on an array of nanoscale levers.

The new technology is still in its infancy; the next step is to make it more complex yet smaller, lighter, faster and more reliable. But mechanical computers are once more on the horizon. For steampunk fans, it's wonderful to imagine spacecraft of the future flying close to the Sun or through the radiation belts of Jupiter, guided not by banks of silicon chips but by the tiny, flickering switches of modern-day Babbage engines.

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MEET THE COLUMNISTS

The Futurist
Stephen Baxter

A pre-eminent science-fiction writer and regular *Focus* contributor, his books include *The Science Of Avatar* and the popular *Destiny's Children* series.

The Insider
Henry Gee

A senior editor of the respected science journal *Nature*, Henry is the author of several books, including *The Science Of Middle Earth*.

The Eco-sceptic
Tom Heap

Tom is an expert on all things green. He presents *Panorama* on BBC One and *Costing The Earth* on Radio 4, which questions accepted truths on green issues.

The Analyst
Robert Matthews

After studying physics at Oxford University, Robert became a science writer. He is a visiting reader in science at Aston University.

The Medic
Michael Mosley

After training as a doctor, Michael joined the BBC to become a presenter, writer and producer. He's *The One Show*'s science man and presented *The Story Of Science*.

The Medic
Michael Mosley

A blood test could help gauge your mental health

There was a guy I knew when growing up, a friend of my father's, who had the most extraordinary mood swings. One day he was the life and soul of the party, the next he was dark and moody. It was many years later, while training to be a doctor, that I realised he must have had an undiagnosed form of manic depressive disorder.

It was people like him that got me interested in becoming a psychiatrist. I soon discovered that psychiatry is a frustratingly inexact science, where definitive diagnoses are hard to come by. But there are a few encouraging hints that this may be changing. For example, researchers from the Karolinska Institutet in Sweden recently reported something unusual in the blood of schizophrenics that could, hopefully, be used as the basis of a simple blood test.

Schizophrenia is one of the most common psychiatric disorders, yet making the diagnosis is notoriously hard. This new study builds on the emerging science of epigenetics. We know DNA isn't a simple instruction manual – that subtle chemical changes within the body, such as the binding of methyl groups to genetic material, can alter how it functions. What the Karolinska researchers found is that schizophrenics have particularly low levels of methylation of the DNA in their white blood cells, and that some antipsychotic drugs raise levels back towards normal. This finding is important because it could not only lead to a blood test but also a better understanding of what is actually going on in schizophrenia.

There have been many false dawns in psychiatry and I am hoping that this won't be yet another one. The brain is the most complex organ in the Universe – which is why it's so difficult to get to grips with what happens when it goes wrong.

WHAT DO YOU THINK?

Has the government been too eager to subsidise flawed 'green' technologies?
post@sciencefocus.com

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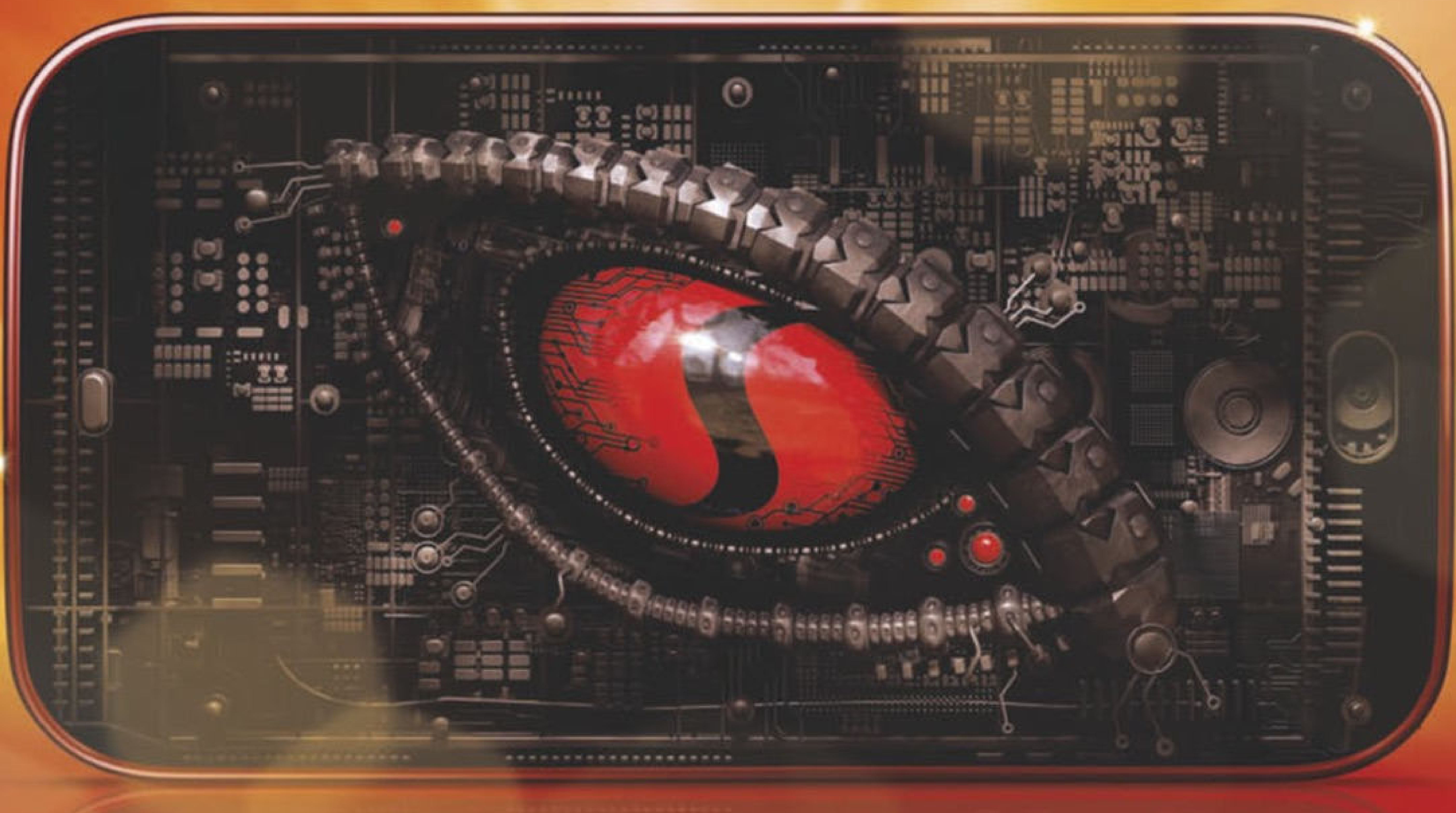

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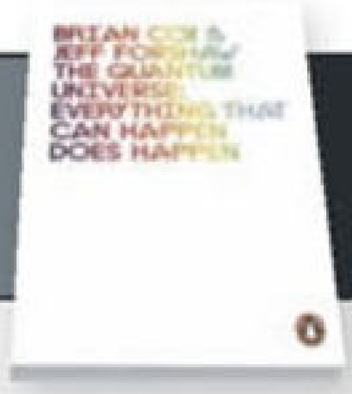
Your Letters

Write in and Win

Message of the month



The letter of the month writer wins a copy of *The Quantum Universe* by Brian Cox and Jeff Forshaw (Penguin Books)

A sense of self

I find what Prof Bruce Hood was saying in the article 'Me, Myself and I' (June, p56) difficult to understand. He says the evidence from neuroscience research shows that the conscious thought to do something comes about half a second later than the action itself, and this leads him to deduce that there is no sense of 'self'. Is this the case with all decision-making? I can understand that this would be true for, say, wanting food or drink as our body may trigger this thought. But what about picking up an empty cup? Why would we pick up an empty cup unless we make a conscious decision to do that?

Also, doesn't this fly in the face of recent research into robotic arms for paralysed patients that are controlled by their thoughts? Surely these work on the principle that the thought comes first?

Dave Richards

Prof Bruce Hood replies: *These experiments show that the point in time when we think we have willed an action occurs after the brain has initiated the movement. Your decision to pick up an empty cup is indeed conscious but not necessarily evidence that you are a coherent self. Likewise, operating external devices by brain activity is possible but that doesn't prove that there is a 'self' in control. If you were in control, then you could empty your mind of all conscious thought – which we can't.*

Bruce Hood argues that there is no such thing as a single 'self'

The truth about dogs

I enjoyed 'The Science Of Dogs' (June, p66) but disagree with the statement that "dogs can't feel guilty for bad behaviour". When I come home, instead of being licked by an excited dog I sometimes find him hiding in his cage. I then look to see what he has done and find an eaten shoe, indoor poo or stolen meat. This shows that dogs do feel guilty as they cannot pick up cues from me. His behaviour precedes seeing me and shows knowledge of right and wrong, and hence guilt.

PW Crosby

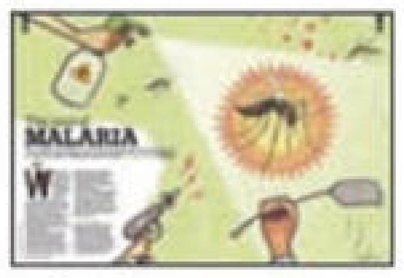
In 'The Science Of Dogs', no comment was made on the negative side. Dogs are the greatest carriers or reservoirs of diseases transmitted by any animal. In India, rabies kills 30,000 people per year and it is quite common for parents to lose all their children from one rabid dog. As a reservoir of leishmaniasis, the dog is partly responsible for some of the 12 million people infected worldwide. Closer to home, cases of children being blinded by toxocariasis have been widely publicised, and so we now have regulations requiring people to scoop up their dog's faeces. The dog's bad behaviour in the picture with the cushion (p71) is because its natural aggressive behaviour has been so repressed.

Roger Webber, Argyll

Perhaps children played a part in turning wolves into dogs ('The Science Of Dogs'). When times were hard, the cubs would have gone into the cooking pot. The children who 'owned' the cubs would have surrendered the snappy ones, keeping back their favourites – the friendly, playful, curious ones. These would survive to breed, with each generation getting more dog-like.

Mike Walsh, Hove

Focus on the poor



I have been a subscriber to *Focus* for several years. However, I do have one criticism: an apparent bias towards the gadgets and gizmos of our affluent society, as well as many articles on science fiction-inspired topics, and very little attention given to the problems of the poor, especially those in developing nations.

Science and technology can be extremely important in helping to relieve hunger and disease, and to facilitate the development of industry and

ADAM GASSON, DARREN CURNOE

WHAT DO YOU THINK?

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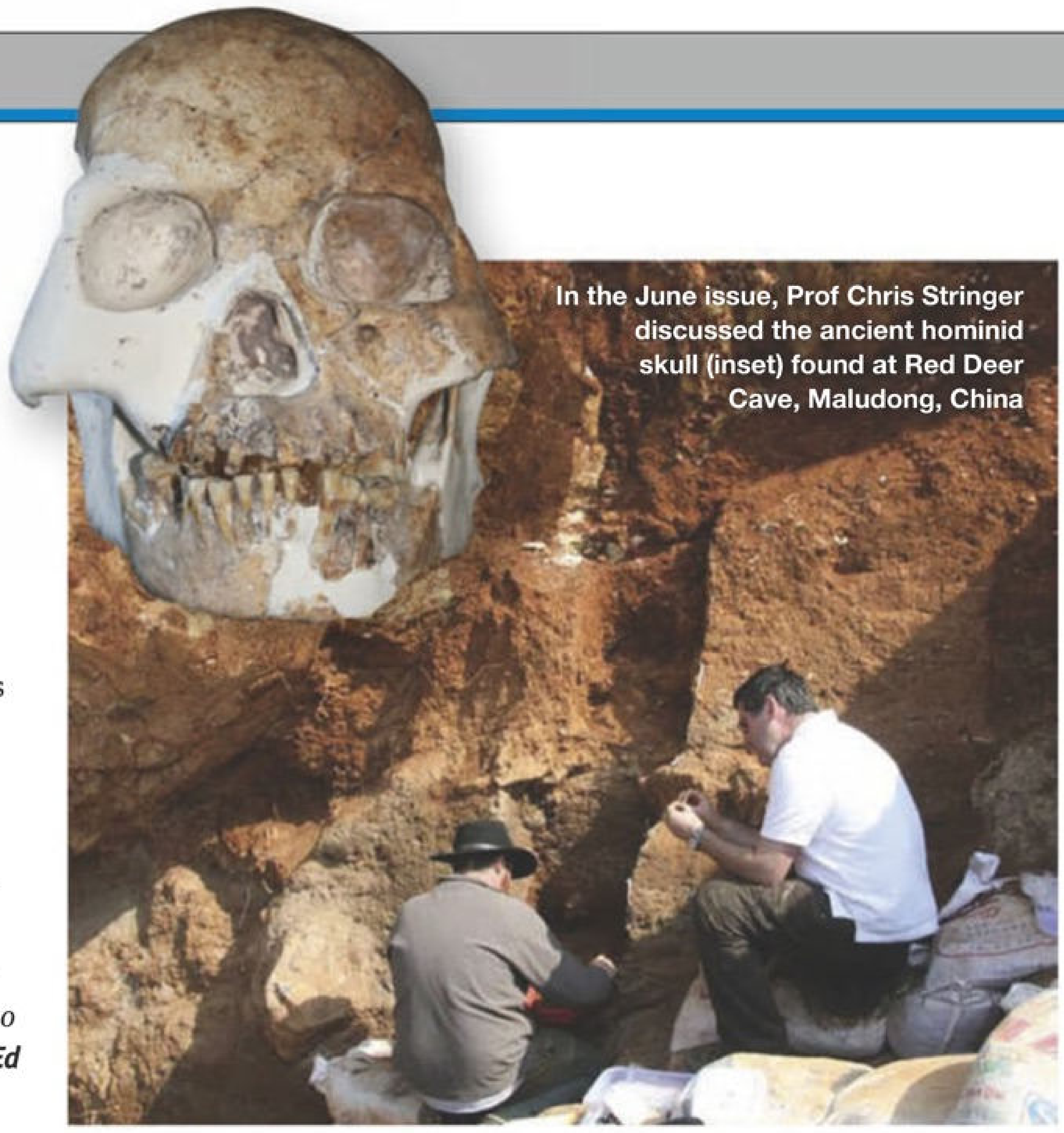

In the June issue, Prof Chris Stringer discussed the ancient hominid skull (inset) found at Red Deer Cave, Maludong, China

commerce. It is understandable you mainly cater for the interests of us Westerners, but how can science help the many billions that struggle to feed, clothe, shelter and protect themselves and their families against famine and disease? One example is mobile phone technology, which is revolutionising trade in many parts of Africa and other countries where more traditional lines of communication are poor.

Maurice Baker

I hope Focus *isn't entirely bereft of the topics you want to read about. For instance, we covered the battle against malaria in our May issue. Do other readers feel the same way? –**Ed***

All at Seagate

After the 'Tried & Tested' article on NAS drives in your March 2012 edition, I purchased the *Focus* Best Buy choice, the Seagate GoFlex Home 3TB drive. I'm afraid to say it's appalling.

The free app provided is beyond basic, access is very limited and temperamental, and the whole thing is unlike Seagate's usual standard. After looking online in forums, especially Seagate's own forum, I'm amazed to find lists of people complaining of the same problems. Maybe you should suggest to *Focus* readers that cloud space is a safer data back-up option than DIY.

Anthony Pearson

Don't believe the hype

Regarding Prof Chris Stringer's article in your June issue (p23), I believe the media jump the gun when it comes to stories about the origins of our species. They focus on how sensational the new evidence is, not on how it advances our understanding. As for his statement that, "It will seem as though the boffins are baffled yet again," I say long live bafflement! It's the instigator that gets people asking the questions that help fill the gaps.

Marc Turland

We live in the age of exaggeration, which sees everything (eg new fossil finds) being billed as the biggest, smallest, hottest, coldest etc. Our attention spans seem to be getting shorter as we are assailed from all sides by television and social media and we seem to need exaggeration to catch our attention and validate our interest.

Steve Callaghan

Not dilithium powered...

I read with some interest the 'Reach For The Stars' article in issue 242 (p46). However, the warp drive in *Star Trek* is not powered by a dilithium crystal. The dilithium crystal regulates the matter/antimatter reaction, in a similar way to how the control rods work in a nuclear reactor.

Matthew Pickard, Southampton

Perfect placebos

Robert Matthews in the June issue (p24) suggests readers might write to you regarding mysteries which might be good subjects for research. I know the 'placebo effect' has been the subject of past *Focus* articles but in my view this effect would be a most fascinating subject for further study. In fact, before starting research into any 'popular medical mystery', an understanding of the placebo effect is essential as that is where the solution to the mystery can often be found.

Research into the placebo effect will not be welcomed by many in the multi-billion-dollar business that is 'alternative medicine' – and indeed many in the world of conventional medicine may also be less than excited about it.

Kieran Keenaghan

Oops... *In the Science Crossword on p107 of the June issue, the clue for 16 Across should have read: 'Biological classification below kingdom but above class'. Solutions missing this answer will be treated as complete for the purpose of the competition*

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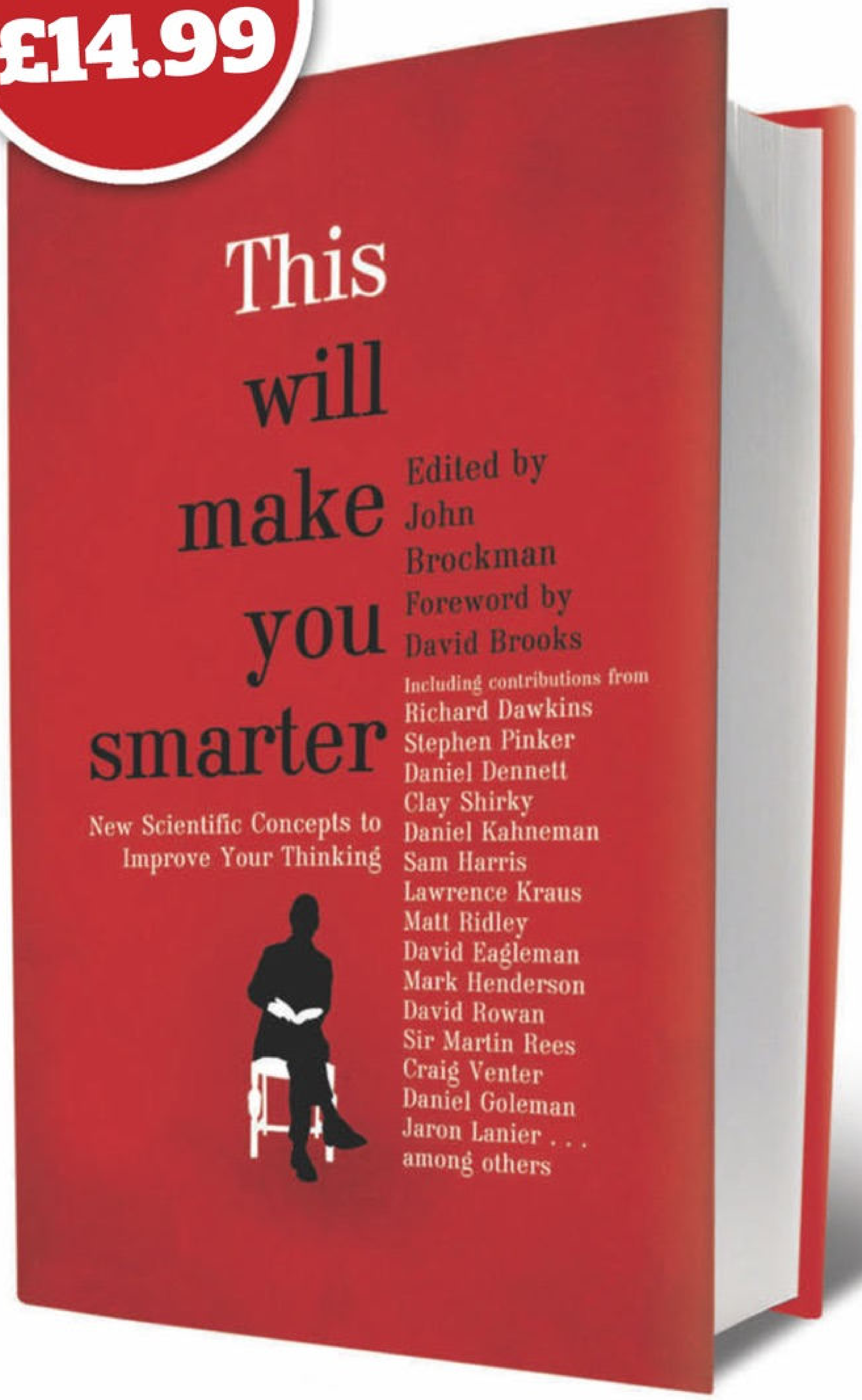

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ONE GIANT LEAP

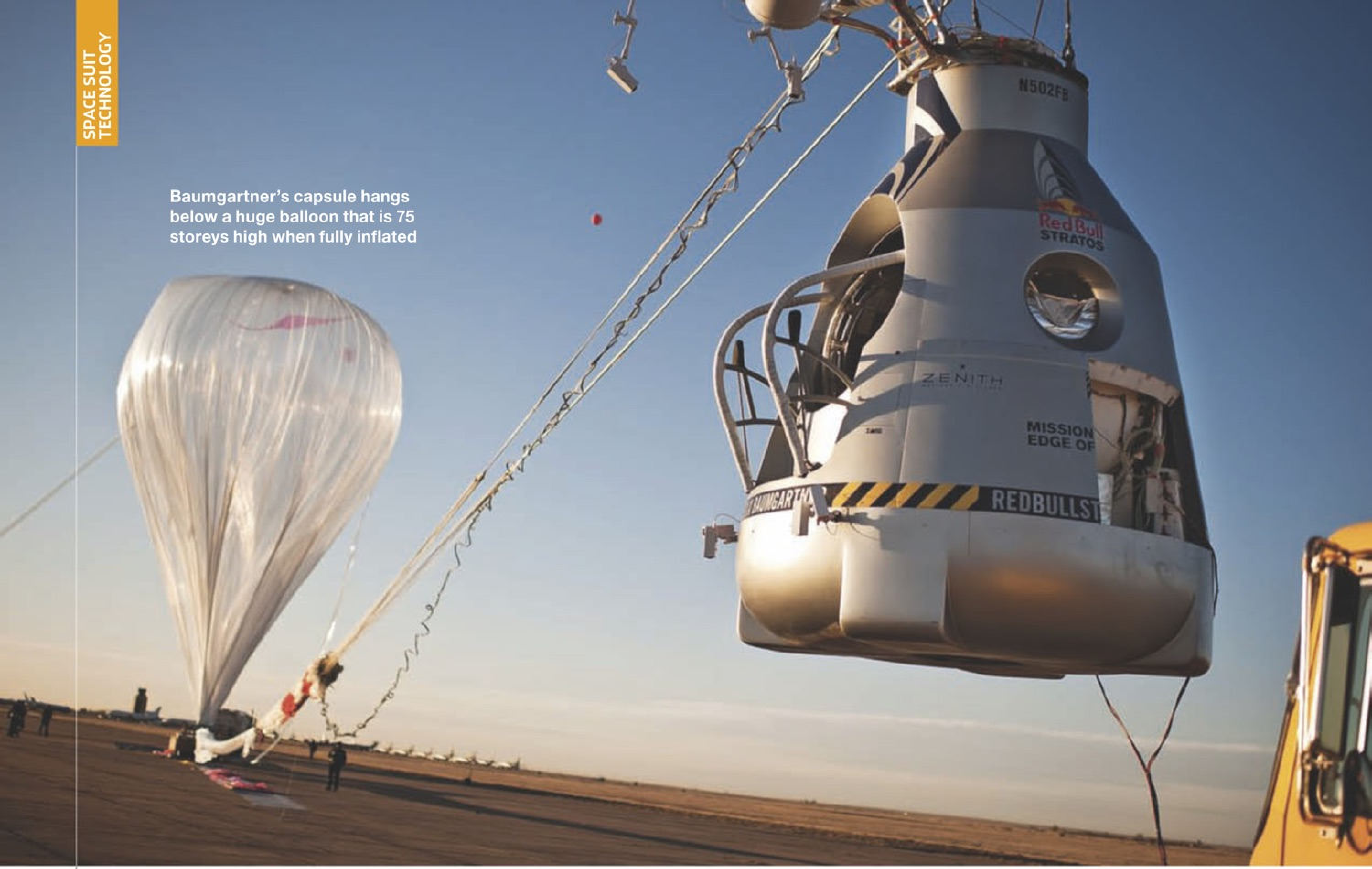
This summer, one daredevil will try to break the record for the highest skydive. **Ian Taylor** looks at how his death-defying freefall could be critical for the future of human spaceflight

Believe it or not, the mission is all about safety. A man will jump from a helium balloon halfway to the edge of space. He'll hurtle head-first through an environment that, without protection, would kill him in 14 seconds. At 120,000ft there will be no air resistance to slow him down, so he'll tear through the sound barrier in less than half a minute. He will become the first person to go supersonic without the aid of a jet engine. Twenty minutes later – assuming he isn't dead – the man will be back on Earth and in the record books. But it's exactly how he *safely* completes the freefall that is the key reason for making the jump.

The man's name is Felix Baumgartner, and he's not your average thrill-seeker. The 42-year-old Austrian has made a living courting and defying death. In 1999, he made the lowest BASE jump in history, off the outstretched arm of Christ the Redeemer in Rio de Janeiro; in 2003, he 'flew' across the English Channel with a carbon-fibre wing strapped to his back. The words 'Born To Fly' are tattooed on his right forearm.

Baumgartner is a test pilot – he just doesn't have a vehicle. And for his next stunt, he will be testing ►

Felix Baumgartner prepares to take the leap with a 71,500ft test jump on 15 March 2012. The real thing will be almost twice the height



Baumgartner's capsule hangs below a huge balloon that is 75 storeys high when fully inflated

▶ the human body and equipment designed to protect it in the lethal environment of the stratosphere, the second layer of the Earth's atmosphere, which stretches from around 30,000 to over 150,000ft above the Earth. Given that several have died trying to dive from such heights (see 'The fall guys', p38), it would be easy to characterise Baumgartner as a reckless daredevil, but he's the opposite: inquisitive, calculating, methodical. "I'm a very careful planner," he says. If Baumgartner is successful, he'll record the longest freefall in history, the highest manned balloon flight and the highest parachute jump.

The jump, named Red Bull Stratos after the energy drinks manufacturer that conceived of and is backing the mission, is about more than just bragging rights. The data collected about Baumgartner's body and the technology encased in his jump suit could be critical for the future of human spaceflight.

"The technology encased in his jump suit could be critical for the future of human spaceflight"

Baumgartner is a careful planner; he'll need to be as just one mistake could mean disaster

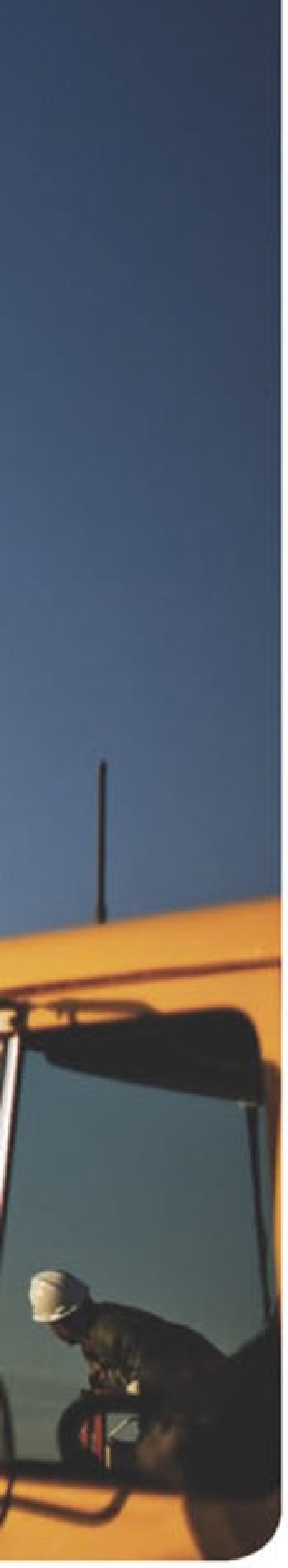
RED BULL X3

To reach the stratosphere without a rocket, you need a balloon – a really big one. Baumgartner's inflatable bag is made from 40 acres of polyethylene. He'll be carried in a pressurised capsule below the balloon, which will be partially filled with helium, a lighter-than-air gas that will expand in the thinning atmosphere as the balloon rises. By the time it reaches its destination 37km (23 miles) up, the balloon itself will be the height of a 79-storey building.

Up in the air

The danger starts not miles above the Earth, but just after launch. "If the balloon breaks while the capsule is lower than 2,000ft, the recovery parachute doesn't have time to open fully and slow the capsule down before it hits the ground," explains Art Thompson, the Stratos technical director. "That's known as the dead zone. We're taking a risk there and Felix realises that if the balloon were to break there is a high probability of injury and possibly death."

At just 0.02mm – about one-tenth the thickness of a sandwich bag – the balloon's extra-thin material makes



it susceptible to many things, including a gentle breeze. So the Stratos team will monitor the weather in fine detail before giving the okay for launch. Once the order is given, it's just two or three hours to the roof of the world. Inside the 6m-diameter capsule (the exterior of which is based on NASA's Gemini and Apollo spacecraft), Baumgartner will be busy the entire time, providing feedback to mission control about his condition and the state of the capsule.

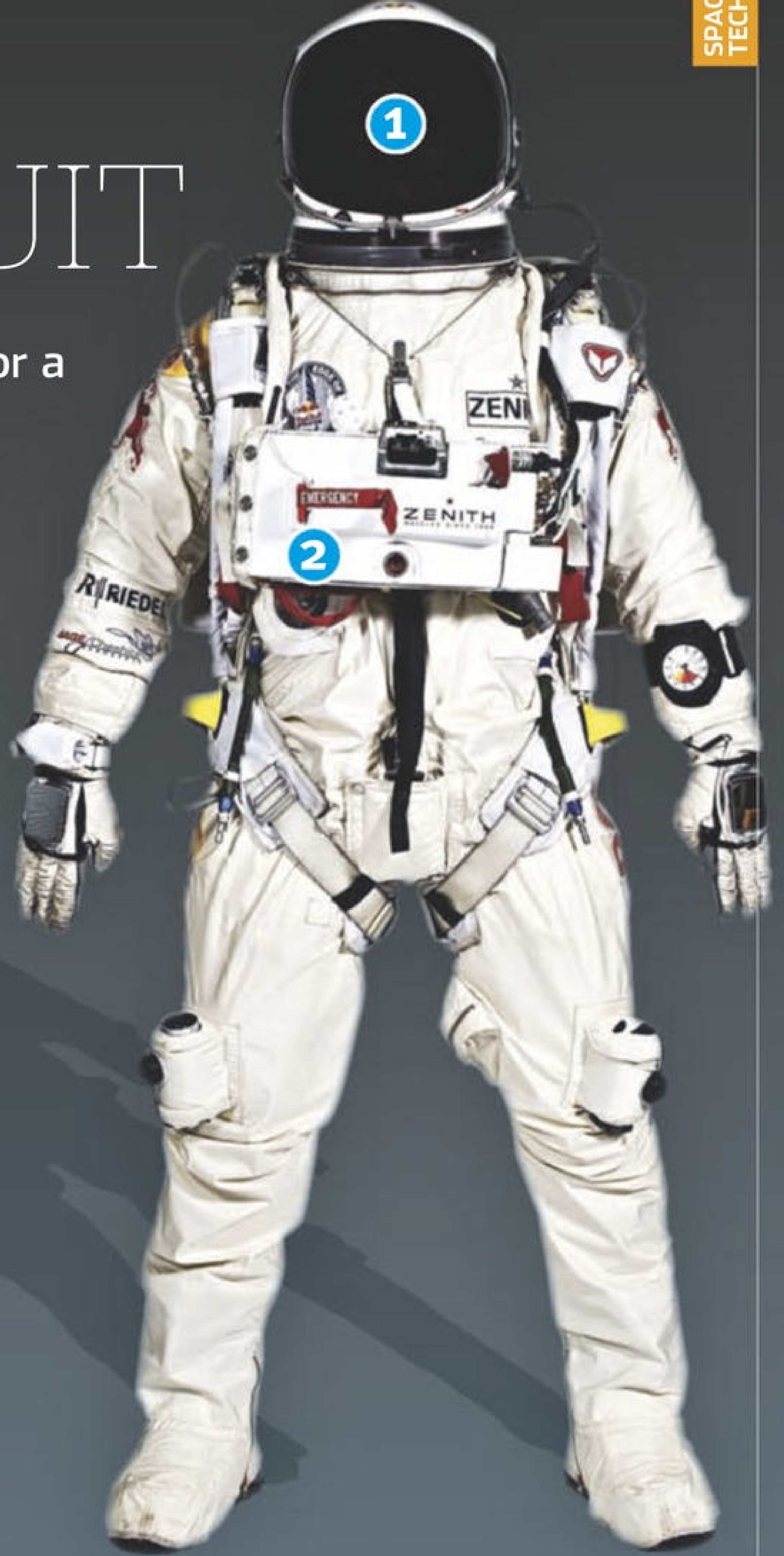
Outside, the cold could reach a frosty –56°C. But more dangerous is the pressure: at 120,000ft, there's almost a total vacuum and the atmospheric pressure is roughly one per cent of what we experience at sea level. Baumgartner will have to equalise his ears like a scuba diver, the altitude making decompression sickness ('the bends') a real issue. As the air thins, nitrogen forms bubbles in the body.

"It causes excruciating pain and at worst it can be lethal," says Dr Andrew Murray of Cambridge University, a physiologist who specialises in extreme medicine and conducts studies at Everest. "If nitrogen gets into your coronary arteries you could die of a heart attack or a stroke if it reaches your brain." To prevent this, Baumgartner will breathe 100 per cent oxygen during the mission and for an hour before to 'wash out' nitrogen from his body.

Sudden depressurisation could also kill him, and this is where the project's real scientific merit comes in. The Stratos team ▶

JUMP SUIT

The technology tailored for a 120,000ft fall

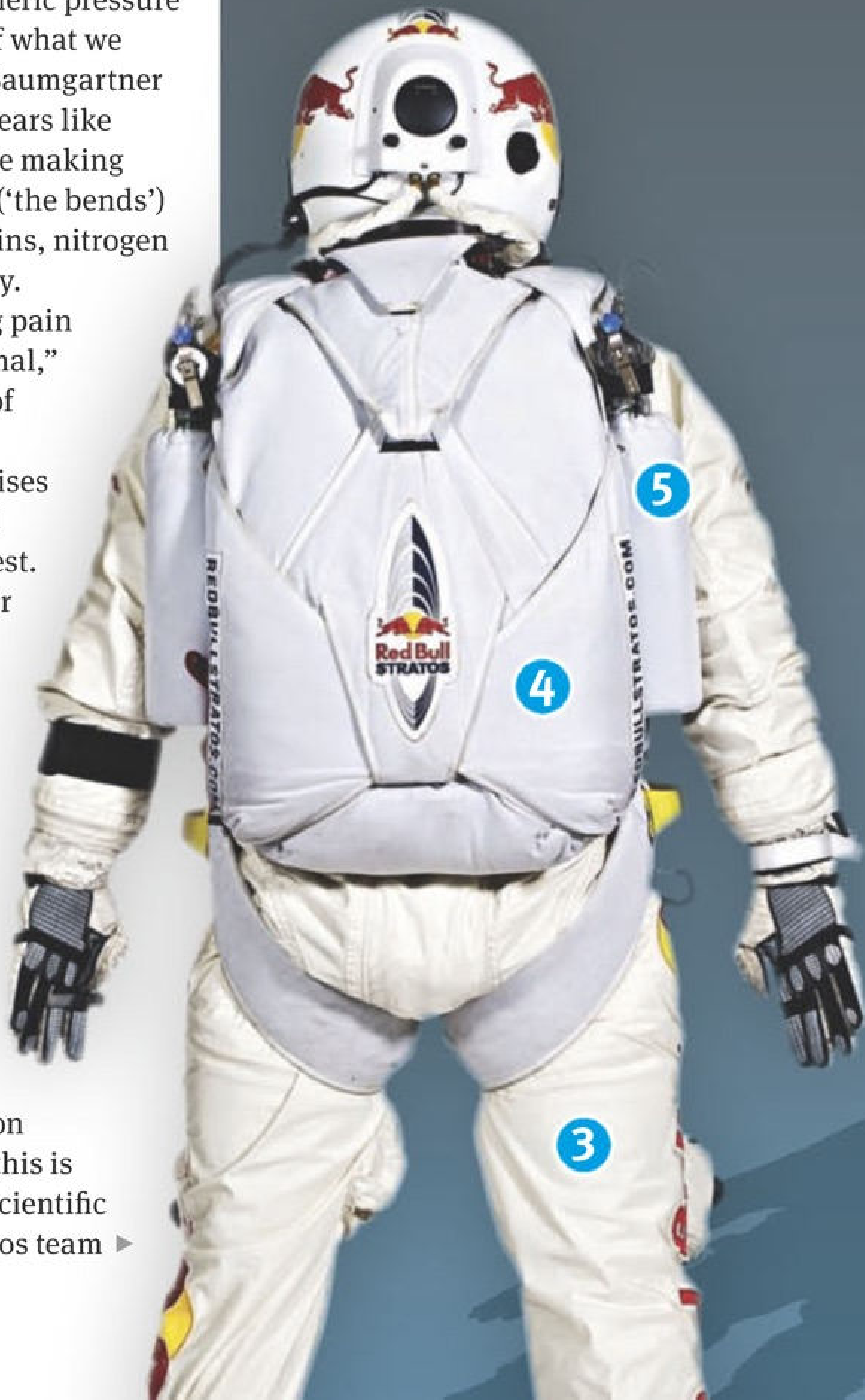


① TEMPERATURE CONTROL

Designed to protect Baumgartner at a temperature range of –68°C to +38°C, the outer layer of the suit is both insulator and flame retardant. The helmet's face shield is also laced with more than 100 heating wires that prevent his breath from frosting up the inside of the face plate.

② CLOUD COMPUTING

The chest pack, powered by two sets of lithium-ion batteries, includes a wide-angle HD video camera, voice transmitter and receiver, accelerometer and instruments that measure biometrics, plus the pitch and angle at which Baumgartner is falling. G-force will be measured by a G-meter strapped to his wrist: if this registers 3.5G for more than six seconds during freefall, the drogue chute will deploy automatically.



③ ARTIFICIAL ATMOSPHERE

A gas-filled bladder in the suit's second layer will maintain an internal pressure of 3.5psi, protecting against the dangers of altitude sickness. At 35,000ft the suit will depressurise, giving Baumgartner some room for manoeuvre to track his landing site.

④ SAFETY CHUTES

The suit packs three parachutes. A drogue chute, released by a ring on the left index finger, can be deployed during freefall to provide stability and prevent a catastrophic flat spin – even at supersonic speed. Baumgartner's main and reserve chutes are the same design he usually jumps with, only 2.5 times larger. If he loses consciousness before deploying a chute, the reserve will deploy automatically at 2,500ft.

⑤ AIR SUPPLY

Two tanks of 100 per cent oxygen will be strapped to his back. Baumgartner will breathe this for two hours before launch to eliminate nitrogen from his body, which could form life-threatening bubbles in his system at altitude. In total, the whole suit weighs 118kg.

▶ has built a next-generation space suit (see p37), a pressurised capsule and biometric monitoring technology – all designed to keep Baumgartner alive. "The capsule will be pressurised to the equivalent of 16,000ft in altitude, and once he exits the capsule, Felix's suit will be pressurised to the equivalent of 35,000ft," says Dr Jonathan Clark, the team's medical director.

If they work, the suit and capsule will prevent decompression sickness and ensure that Baumgartner doesn't face the near-vacuum of the stratosphere. If the technology fails, he's a dead man; he'll be far above

Joe Kittinger just after his 102,000ft freefall

The next generation: Kittinger shakes the hand of the man who could take his skydive record

THE FALL GUYS

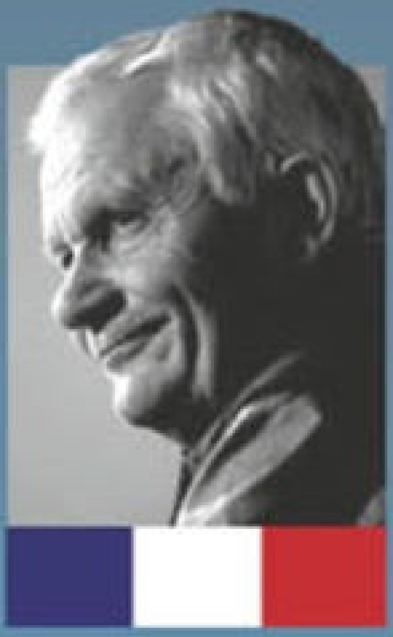
The determination and tragedy of the men who fell to Earth

The Russian military man

In November 1962, a high-altitude balloon carried Pyotr Dolgov, a colonel in the Soviet air force, to an altitude of 86,000ft. He was testing a new pressurised suit for the Vostok space programme, which had put Yuri Gagarin into orbit the year before. But as Dolgov exited the balloon his visor struck a part of the platform and cracked. The mishap proved fatal as the suit depressurised, exposing the Russian to the lethal environment of the stratosphere. He died almost instantly from hypoxia, his body quickly deprived of oxygen. Although the West didn't learn of his fate for some years, it is thought that his body returned to Earth and was retrieved by Soviet officials.

The American truck driver

Nick Piantanida, an American adventurer and former truck driver, made several attempts to break the record for high-altitude skydiving. His third, in 1966, would be his last. During the ascent, his helmet suffered a catastrophic loss of pressure at 57,000ft. His ground team heard a whoosh of air on the radio and a single word: "Emergency" – silenced midway through. They remotely jettisoned the balloon and the capsule carrying Piantanida fell safely to the ground. However, the loss of pressure had done its damage. Piantanida fell into a coma, brain-damaged, and died four months later. Even now, nobody knows what caused the loss of pressure. The most likely scenario is that, for reasons unknown, he lifted his mask himself and could not shut it again.



The Frenchman who won't give up

The numerous, failed attempts of Michel Fournier show that when planning a high-altitude balloon jump, getting up can be just as difficult as getting down. The 68-year-old Frenchman, formerly a colonel in the air force, has been planning Le Grand Saut (the big jump) for 20 years. But the super-lightweight material used on his balloon has torn twice, ending the missions before they've gotten off the ground. A third attempt in 2008 also ended in somewhat deflating circumstances. The balloon, reinforced to prevent another tear, unexpectedly detached from the capsule while Fournier was sat inside, waiting on the tarmac. It floated off and landed in tatters miles away. He may lack the big-money backing of the Red Bull Stratos mission, but he's not short of gumption: Fournier plans to make another attempt some time this year, even if Baumgartner gets there first.

RED BULL X4, PRESS ASSOCIATION, GETTY

Baumgartner prepares to leave the capsule during the 71,500ft test jump. He needs to make a clean exit so as not to go into a potentially lethal spin

"Pilots and passengers could escape from a spacecraft mid-flight"

what's known as the 'Armstrong line', which denotes the altitude where atmospheric pressure is so low that water boils at body temperature. The air inside his lungs would multiply over 100 times in volume and, if he tried to hold his breath, his lungs would rupture. Baumgartner would be dead in seconds, although his body would continue to expand into whatever space the suit allows.

Learning from leaping

Catastrophic loss of pressure has killed several high-altitude skydivers in the past. But one man on the Stratos team has already survived depressurisation at altitude: Joe Kittinger, a retired US Air Force colonel who holds the record for the highest parachute jump – a record that has stood for 52 years. Now 83, Kittinger will serve as the mission's Capcom 1: Baumgartner's primary contact for capsule communication with the ground team far below.

In 1960, Kittinger set his record – 102,000ft – while testing a new parachute system for the Air Force. Unlike the full-pressure suit Baumgartner will be testing, Kittinger's suit had separate sections pressurising different parts of his body, including his hands and feet. "On the way up, the rubber tube connecting the right glove to the air source broke," he says. "When I arrived at 40,000ft the suit was pressurised, the glove wasn't."

Kittinger's hand ballooned to more than twice its size, filling the glove and only returning to normal after a few hours on the ground. But because Baumgartner will wear a full-pressure suit, the loss of a glove would mean he'd lose *all* pressure. "If he lost a glove, he would be dead," Kittinger explains.

Stratos will test the effectiveness of the new space suit. "As nobody has done this before, this data will be invaluable in advancing human space exploration," says Jonathan Clark. "The monitoring system we use is also being evaluated for use on upcoming suborbital spaceflights. Commercial space companies are evaluating crew escape systems like the one we are using for their upcoming flight tests."

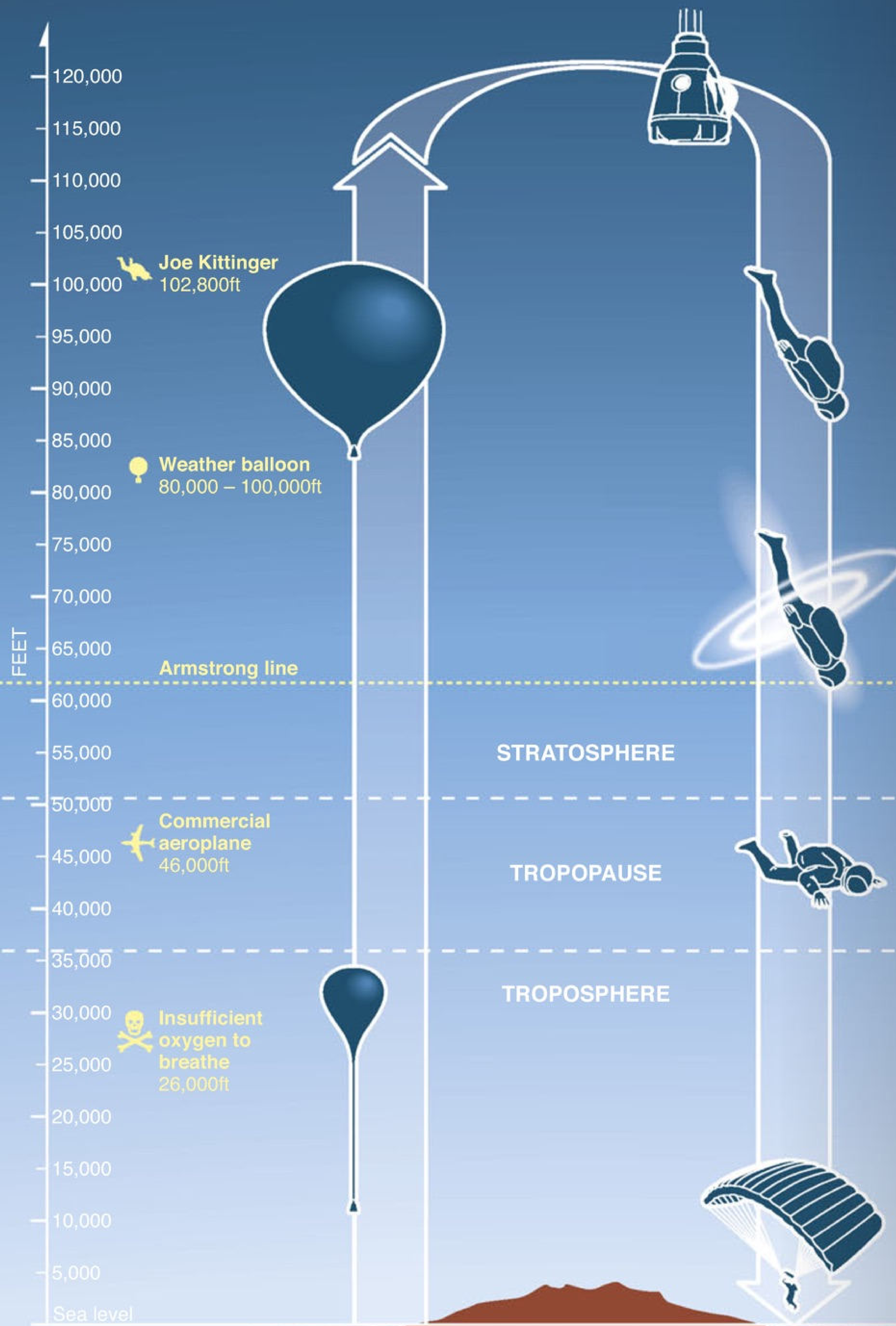
Clark understands the potential benefit of the technology better than anyone: he was a NASA flight surgeon for years, as was his wife, Laurel. She was on-board the Space Shuttle Columbia when it broke up on re-entry to the Earth's atmosphere in 2003, killing all seven crew members.

If the Stratos suit works, it could inform the design of suits worn by future astronauts, aviators and space tourists. By donning a similar suit and jumping, pilots and passengers could escape from a spacecraft mid-flight, saving themselves from the fate that befell the crew of the Columbia disaster. Based on a 71,500ft test jump in March, the Stratos team already know that someone can make a clean exit and maintain stability in the stratosphere. "It could be important information for researchers looking ▸

Kittinger (left) at the helm of Stratos Mission Control

DOWN TO EARTH

How Felix Baumgartner will plummet from the stratosphere



1. FLOATING UP TO 120,000FT WILL TAKE LESS THAN THREE HOURS. At that altitude, Baumgartner will wait for clearance from his team and run through a 39-point checklist. He'll then manually depressurise the capsule, stand up (an effort in itself in a 118kg suit), open the door and step out onto a platform.

2. THE ONE SMALL STEP IS CRUCIAL. As the air around his body is so thin, there's nothing to slow him down. He must adopt a stable 'delta' position (head forward, arms to the side, legs out behind) to reduce drag and prevent an uncontrollable spin.

3. BAUMGARTNER SHOULD GO SUPERSONIC, clocking a speed of over 700mph after half a minute of the highest, fastest freefall in history. Sound waves known as sonic booms might be created as he hits the sound barrier, but nobody knows for sure how they would affect his fall or suit.

4. FREEFALL WILL LAST MORE THAN FIVE MINUTES: ANOTHER RECORD. The closer Baumgartner gets to the troposphere, the more air molecules he'll encounter – generating resistance that slows him down.

5. BAUMGARTNER DEPLOYS HIS PARACHUTE AT 5,000FT. At this altitude he will have slowed to around 170mph. It will take a further 5-10 minutes to reach the ground. His total flight time from the leap to terra firma is 15-20 minutes.

Technology developed by the Stratos team could find its way to Virgin Galactic's SpaceShipTwo, protecting future space tourists

▶ to establish emergency bailout protocols," says Clark.

Provided the suit holds firm, the balloon flies true and there are no problems with the capsule, all that remains is, well, the gravity of the situation. The jump starts with a step through a circular door in the capsule onto a small platform. "At 120,000ft the air is so thin that if I have an unstable exit, I won't be able to work against the air's resistance for stabilisation," says Baumgartner.

A stable trajectory would stop him from spinning like a propeller. "A flat spin would essentially create a centrifuge out of his body," says Dr Murray. "It would draw the blood away from his brain and he could start to lose consciousness."

In the 1940s and 1950s, ejections from fighter aircraft resulted in pilots spinning at rates of 180-250rpm spins – all were fatal. If the centre of rotation is in the upper part of the body, blood rushes toward the feet, which can cause a blackout. And if the rotation is centred in the lower part, blood rushes toward the head, the effects of which range from a feeling of pressure to bleeding in the brain. "The longer the spin lasts, the more dangerous it becomes," warns Clark.

In 1959, Kittinger experienced just such a spin. His drogue parachute – which adds drag and stability – deployed too early and wrapped around his neck, causing a flat spin at a rate of 120rpm. He blacked out, his life saved by the regular chute, which opened automatically at 10,000ft.

Should Baumgartner make an unstable exit and go into a spin, technology should also come to his aid. A device on his wrist will measure the G-forces on his body – if he experiences over 3.5G for more than six seconds his drogue chute will deploy automatically and stabilise his fall… provided it all works smoothly.

> "There's no way of knowing whether it will rip his suit apart"

However, the drogue chute would slow Baumgartner down and could rob him of becoming the first person to travel at supersonic speed – the biggest prize and a genuine scientific frontier. Nobody has fallen through the sound barrier before, so nobody knows what will happen.

The crew of the ill-fated Columbia mission. The Stratos space suit could help prevent a similar loss of life

One possibility is that shockwaves or sonic booms will be created as Baumgartner exceeds the speed of sound. When a supersonic jet breaks the sound barrier, it creates pressure waves in the air in front and behind it, like the ripples a boat creates on the surface of a lake. Eventually these waves collide, creating a single almighty shock wave and a crack like thunder. If that happens, there's no way of knowing whether it will send Baumgartner spinning off course, rip his suit apart, or do nothing at all.

Whatever happens, the Stratos project will generate invaluable information for mankind if we're to become a space-faring species. NASA may have grounded the Space Shuttle but its successor, the Orion programme, is set to carry astronauts back to the high frontier within a decade. And later this year, Richard Branson's company Virgin Galactic will take its first space tourists to low-Earth orbit on the SpaceShipTwo space plane. Almost 10 years after the loss of Columbia, we're still learning how to survive the risks involved.

"More people are going to be travelling to space and they will need new kinds of suits and safety procedures – hopefully, we are pioneers in developing something for their needs," says Baumgartner. So believe it or not, when a man makes a death-defying jump from the stratosphere this summer, it's all in the name of safety. ■

Ian Taylor is commissioning editor of* Men's Health *magazine

Look out for *Space Dive*, a special BBC programme this summer on the Stratos project.

FIND OUT MORE

www.redbullstratos.com
The Red Bull Stratos project

VIRGIN GALACTIC, NASA, ILLUSTRATION BY ACUTE GRAPHICS

ILLUSTRATION BY TIM MARRS

Risky business

What caused the financial meltdown? Neuroscientist and ex-Wall Street trader **John Coates** says we've overlooked a crucial aspect of financial risk: biology

Q How does biology influence economics?

A I take issue with an idea that permeates every academic discipline – that you can separate mind and body. There's a tendency in neuroscience to stop at the neck, but that ignores a good part of the signals coming into the brain. There's a similar tendency in economics to ignore the profound influence of the body on risk-taking.

It's assumed that our appetite for risk is a trait that we're born with, but we're built so that our appetite for risk changes. If we're injured, our body tells us not to take risk. If we're hungry, maybe our body tells us to take more risk. In my book, *The Hour Between Dog And Wolf*, I try to illustrate how profoundly physical risk-taking, and specifically financial risk-taking, really is.

Q Is it the cause of the current turmoil?

A I don't think biology causes bull [upward-moving] or bear [downward-moving] markets. What we think is that if there's a prolonged winning streak, when a trader is making an above-average profit and expecting an above-average bonus, testosterone levels build up in the body and shift risk preferences past the point at which it's effective. Risk-taking then becomes risky behaviour. During a bear market, stress response has the effect of reining in risk appetite so that the market goes into a crash. At this point interest rates have no effect and that's precisely what we've seen. During the credit crisis, the state had to step in and start buying risky assets first, before the financial community snapped out of its funk.

Stress response has the effect of reining in risk appetite, so that a bear market goes into a crash

Q How are market traders affected by stress?

A The brain always assumes that at some point the stressor will be physical, so it prepares our body for it. When volatility [in the market] increases, so do your blood pressure and your breathing, and you sweat a bit more. Even though traders are sitting down, clicking a mouse, making calls and staring at a screen, they're experiencing the same physical symptoms as a surfer riding a monster wave or a soldier sprinting across No Man's Land. The brain is not built to process information dispassionately, as a computer would. It always sifts this information for its implications for movement.

When you're reading a novel, for example, it's just words on a page but our body revs up and down. Just as novels cause your body to react, so do the prices on a broker's screen.

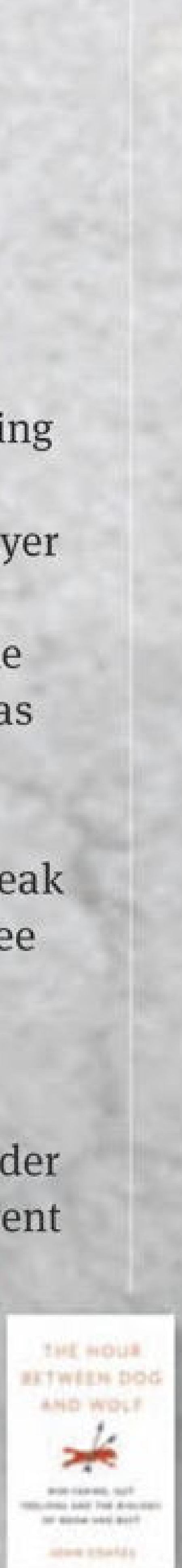
Q How can we stop biology from having a detrimental impact?

A Managers should be looking at winners, as they're the ones who are most susceptible to a testosterone feedback loop. Every blow-up in the banks I've seen, like the recent one at JP Morgan, occurred at the hands of a trader who they thought walked on water. They've raised his risk limits and paid him ever-increasing bonuses, but that creates euphoria and a feeling of omnipotence, which then causes him to put on trades with terrible risk/reward trade-offs.

Instead, they should have something like the rain break at Wimbledon. Sometimes in a tennis match, a player looks like they're sure to win; then there's a rain break, and by the time they come back out their biology has been reset and the match in some sense starts again. In the banks, a trader who's been on a winning streak could be pulled off the floor for three weeks to let his biology reset.

The other way of controlling unstable risk-taking is to diversify biology – have more women and older men, because they have very different biologies from the younger men. ■

Dr John Coates is a senior research fellow in neuroscience and finance at the University of Cambridge. His latest book is *The Hour Between Dog And Wolf* (Fourth Estate, £20)



THE WORLD'S DEADLIEST VOLCANOES

With the BBC's *Volcano Live* soon to hit our TV screens, **Bill McGuire** reveals the most lethal eruptions in waiting

BBC TWO

Catch *Volcano Live* from 9 to 12 July on BBC Two. Kate Humble and Professor Iain Stewart present the show live from the Kilauea volcano on Hawaii's Big Island.

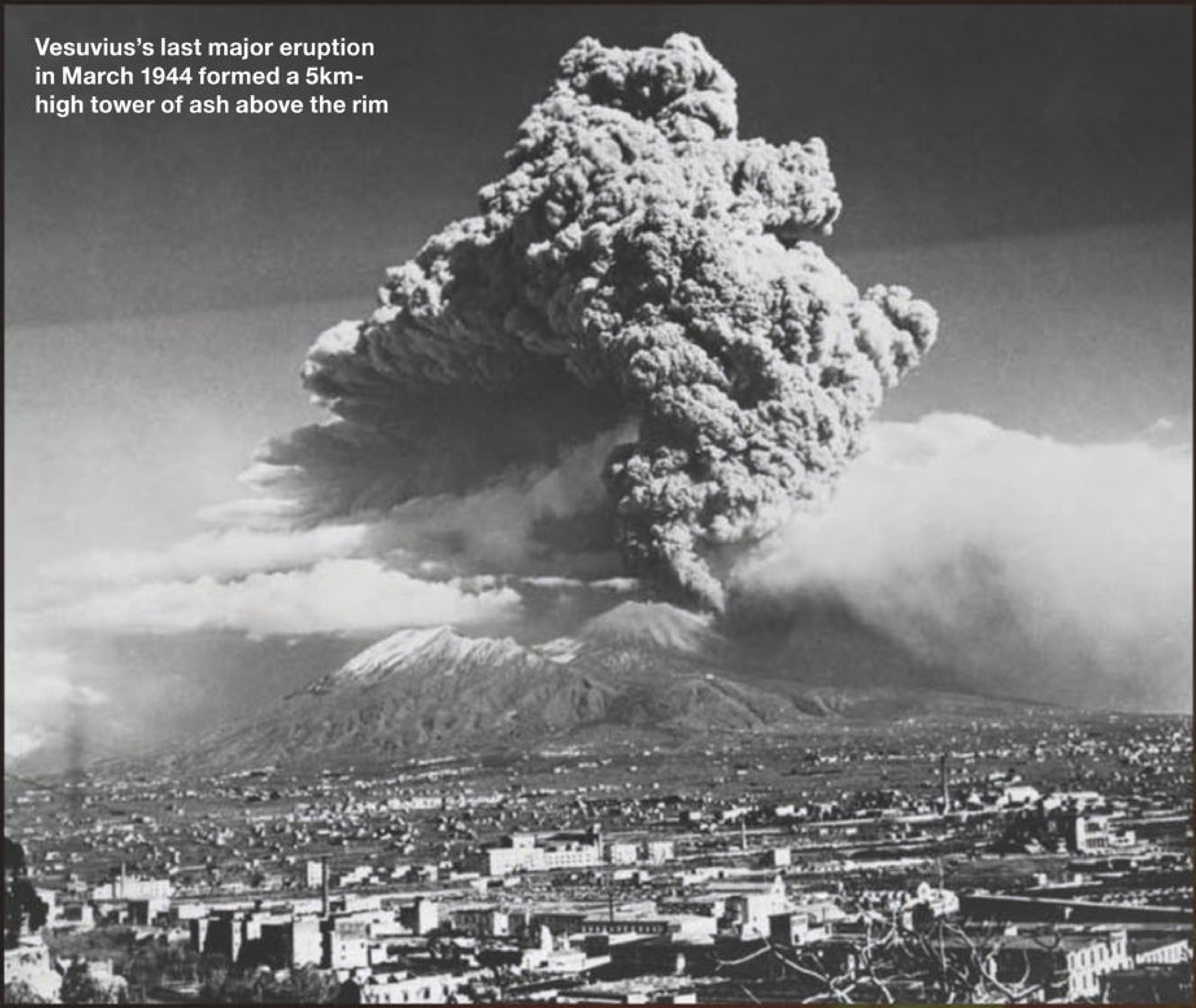
THINKSTOCK

Eruptions from Ecuador's Tungurahua volcano in 1999 required 25,000 nearby residents to be temporarily evacuated – other volcanoes pose a far greater threat

Volcanoes may not, generally speaking, take as many lives as earthquakes and floods – 92,000 in the last 100 years. But the greatest of volcanic outbursts can bring about a global freeze, worldwide harvest failure and unimaginable loss of life. Around 74,000 years ago, a colossal super-eruption of the Toba volcano in Sumatra may have brought our race to the brink of extinction, while as recently as 1783, famine caused by the climatic impact of an eruption of Iceland's Laki volcano may have led to as many as six million deaths worldwide.

There are at least 1,500 active volcanoes around the world, of which around 50 erupt every year. To most people the idea of a volcano erupting equates to the outpouring of red-hot lava, but this is rarely a killer. Far more lethal are the voluminous quantities of falling ash, the torrents of mud and debris, the towering tsunamis and, perhaps scariest of all, the hurricane-force surges of rock and incandescent gas known as pyroclastic flows.

The five volcanoes described here are adept at wreaking death and destruction in distinctive ways. What they have in common is the huge threat they present to large numbers of people and potentially – in one case – to the entire human race. ▶



Vesuvius's last major eruption in March 1944 formed a 5km-high tower of ash above the rim

VESUVIUS

LOCATION:
BAY OF NAPLES, ITALY
LAST ERUPTION: 1944
MOST DANGEROUS CHARACTERISTIC: MORE THAN HALF A MILLION PEOPLE DIRECTLY THREATENED BY PYROCLASTIC FLOWS AND SURGES

The excavated ruins of the Roman cities of Pompeii and Herculaneum provide awful testimony to the perilous threat presented by this twin-peaked volcano. During the famous 79AD eruption, the inhabitants of the two communities were engulfed in the rapidly moving torrents of incandescent ash and superheated gas known as pyroclastic flows. Death was agonising but rapid, a single breath burning the throat and destroying the lungs. So high were the temperatures of the flows that water in people's bodies turned instantly to steam, causing the skulls of the dead to explode.

Vesuvius deserves a place on any list of the world's deadliest volcanoes because of the sheer number of people now living in close proximity. Furthermore, the volcano is particularly unpredictable, in that while it can sometimes erupt almost continuously for centuries – as it did prior to its last significant outburst in 1944 – it can also lie dormant for equally long periods, which was the case in the run-up to the 79AD blast. Since the end of World War II, rapid construction, much of it unplanned or illegal, has resulted in the population of the highest-risk 'zona rossa' (red zone) exploding to more than 600,000 people. They will all be in grave danger when, as will inevitably happen at some point, Vesuvius springs to life once again.

Vesuvius can erupt almost continuously, but it can also lie dormant for long periods

Scientists do not know how big the next eruption will be, nor how much warning they will be able to give. Despite Vesuvius being one of the world's most closely monitored volcanoes, the early signs of ground swelling and clusters, or swarms, of small earthquakes may provide less than two weeks' warning and give few, if any, clues as to the nature or scale of the eruption to come.

WEAPONS OF ERUPTION

The threats posed by volcanoes take many forms

Pyroclastic flows are torrents of hot rocks, gas and ash capable of obliterating all before them. They are generated when ash columns or domes of lava collapse before hurtling down the slope.

Volcanic mudflows, or lahars, are unstoppable and lethal. They are most commonly generated by heavy rain falling on loose ash, or by the passage of pyroclastic flows across glaciers.

Volcanic ash is formed by the fragmentation of ejected magma. It can damage crops severely, disrupt transport and communications and cause roofs to collapse over wide areas.

SUPERSTOCK X2, THINKSTOCK X2, BILL MCGUIRE X4

CUMBRE VIEJA

LOCATION: LA PALMA,
CANARY ISLANDS
LAST ERUPTION: 1971
MOST DANGEROUS CHARACTERISTIC: CATASTROPHIC COLLAPSE OF THE VOLCANO'S WEST FLANK TRIGGERING A MAJOR TSUNAMI IN THE NORTH ATLANTIC

Cumbre Vieja could trigger an Atlantic tsunami

La Palma's Cumbre Vieja (Spanish for 'old summit') volcano is the most active in the Canary Islands. Since the 16th century, half a dozen moderate eruptions have caused damage, though casualties have been mercifully few. Looking ahead, concern is focused on a future collapse into the North Atlantic of the volcano's western flank.

Such behaviour is uncommon, but not unheard of. Countless volcanoes reveal evidence of flank collapse at some point in their life cycles. Indeed, the Canary Island volcanoes have themselves suffered a dozen previous collapses, including one around half a million years ago that removed a massive chunk of a volcano to the north of La Palma. Now, to the south, very rapid growth since Cumbre Vieja's birth around 125,000 years ago has constructed a particularly steep-sided volcano that is ripe for collapse once more.

In 1949, during the last eruption but one, severe ground shaking accompanied the opening of a 4km (2.5-mile) long system of fractures along which a colossal chunk of the western half of the volcano dropped seawards by several metres. GPS monitoring reveals that this enormous detached rock mass is continuing to creep and will at some point – maybe in 10 years' time, or in 100, or in 10,000 – plunge into the adjacent ocean. Computer modelling of the event predicts the formation of a tsunami hundreds of metres high that will devastate the Canary Island archipelago in less than an hour.

Some scientists predict that the tsunami will remain destructive even at distances of thousands of kilometres from La Palma, bringing death and destruction to coastlines as far away as the UK and North America. These conclusions are, however, controversial and by no means a consensus view.

Landslides result from the collapse of a volcano's flank. Rapidly growing volcanoes quickly become destabilised by earthquakes, or by magma forcing its way into the structure.

Volcanic gases, especially sulphur dioxide, are pumped into the atmosphere in vast quantities during eruptions. These gases block the Sun's heat, which can cause severe global cooling.

Volcanic bombs are solid chunks of lava blasted out during eruptions. Luckily, it's usually only volcanologists who have to dodge them since they rarely travel more than a few kilometres.

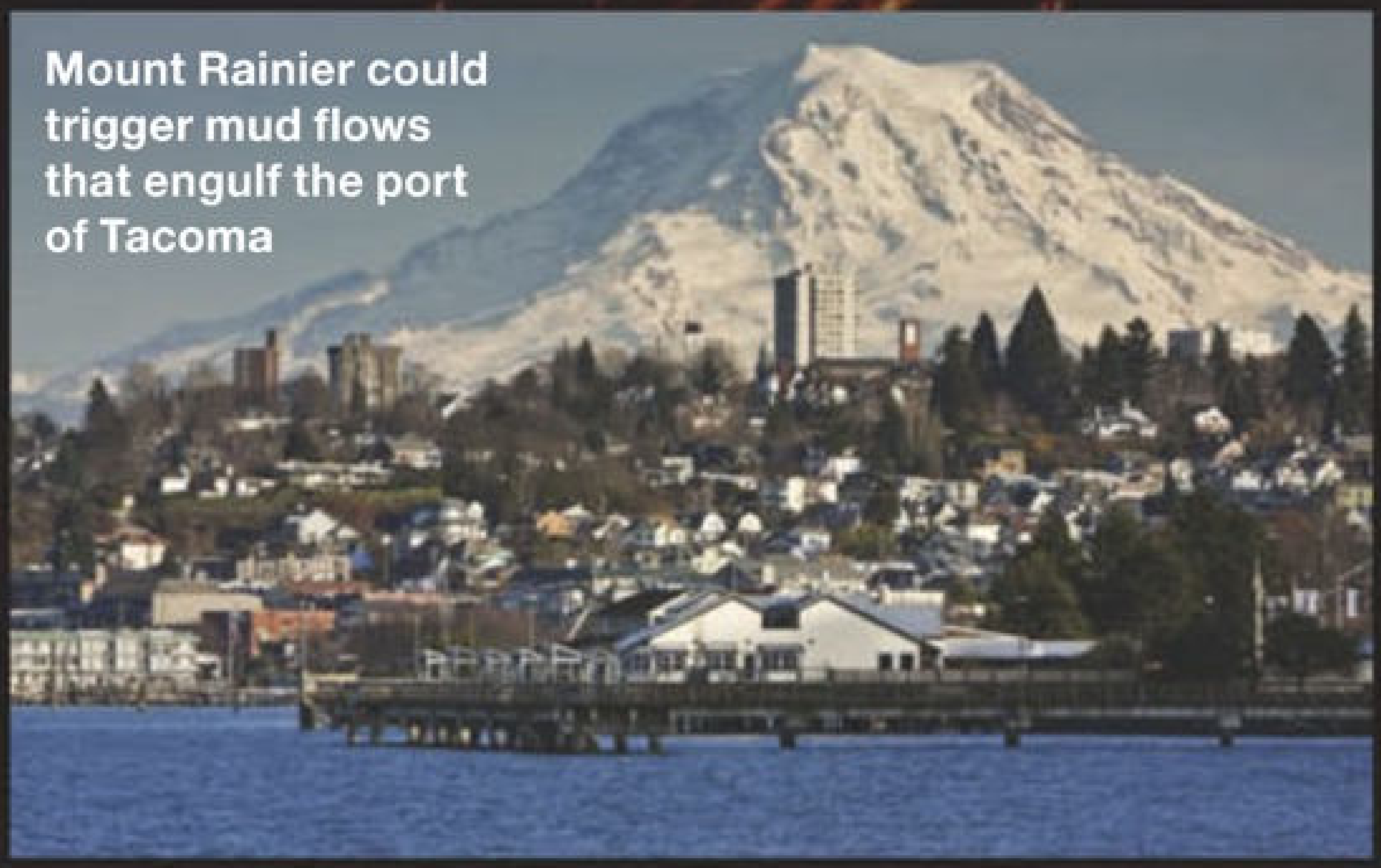
MOUNT RAINIER

LOCATION: CASCADE RANGE, WASHINGTON STATE, USA
LAST ERUPTION: POSSIBLE STEAM OUTBURST IN 1894
MOST DANGEROUS CHARACTERISTIC: FAST-MOVING MUDFLOWS CAPABLE OF REACHING INHABITED AREAS

Like Vesuvius and Mount Fuji, this monster volcano is located perilously close to an area of dense population – the cities of Seattle and Tacoma in the US state of Washington. Rainier has been dormant for at least 118 years and although past eruptions have produced heavy ash fall and pyroclastic flows, the real hazard here is mud.

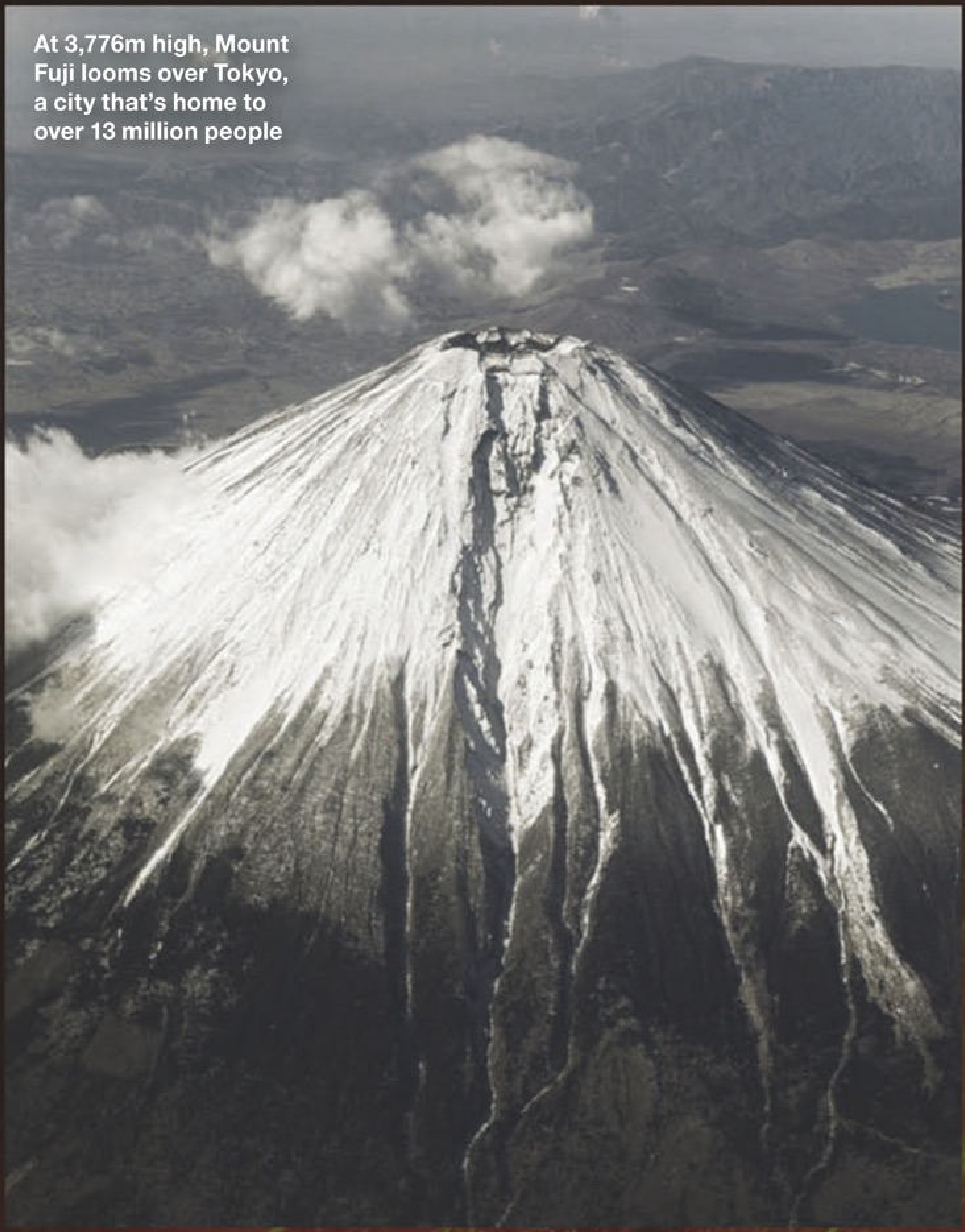
Eruptions during prehistoric times resulted in the catastrophic melting of the volcano's thick ice cover, generating massive mudflows. A repeat today of the biggest – the Osceola Mudflow, some 5,600 years ago – could see torrents of mud wiping out several nearby towns and ploughing into downtown Seattle and the port of Tacoma.

The fact that 150,000 people live in homes built on old mudflow deposits highlights the level of the threat, and has galvanised local government officials into planning evacuation routes and installing a mudflow early warning system. However, some communities are not convinced that enough is being done and worry that the next eruption may bring catastrophe. To add to their woes, it is perfectly possible that glaciers may melt, starting landslides – spawning large, destructive mudflows – without an accompanying eruption, and therefore without any warning.



Mount Rainier could trigger mud flows that engulf the port of Tacoma

CORBIS, SUPERSTOCK, PRESS ASSOCIATION



At 3,776m high, Mount Fuji looms over Tokyo, a city that's home to over 13 million people

MOUNT FUJI

LOCATION: HONSHU ISLAND, JAPAN
LAST ERUPTION: 1707
MOST DANGEROUS CHARACTERISTIC: HEAVY ASH FALL ACROSS THE GREATER TOKYO METROPOLITAN AREA

Towering over the capital on the Japanese island of Honshu, the iconic, snow-capped Mount Fuji presents a direct threat to more people than any other volcano on Earth. This giant has been docile since its last eruption in 1707, but the 35 million inhabitants of the Greater Tokyo metropolitan area await its awakening with some trepidation.

Most of the 'Younger Fuji', built on the remains of older volcanic centres, is formed from quietly erupted lava flows. But the 1707 episode was far more violent, blasting out sufficient ash to fill Wembley soccer stadium more than 500 times over. The worry is that the next eruption could be similarly explosive.

Many volcanoes are far more proficient at vomiting great quantities of ash than Fuji. The problem is that the huge extent of urbanisation in the vicinity enormously magnifies its potential impact. While the least glamorous of all volcanic hazards, the effects of volcanic ash are manifold and can be severely damaging – polluting water supplies, destroying crops, poisoning livestock and causing countless roofs to collapse. A future eruption on the scale of 1707 could dump as much as 15cm of ash across the region. The damage and economic mayhem, was forecast in a Japanese government report to cost $21 billion (£13 billion).

Uturuncu is one of the fastest rising volcanoes in the world. An eruption there could threaten us all

UTURUNCU

LOCATION: BOLIVIA
LAST ERUPTION: 300,000 YEARS AGO
MOST DANGEROUS CHARACTERISTIC: CATACLYSMIC EXPLOSIVE ERUPTION WITH A POTENTIAL GLOBAL IMPACT

Uturuncu is a volcano so obscure that even most volcanologists had not heard of it until recently. Hidden away in southwest Bolivia, this is a volcano that has not erupted for 300,000 years. So it was something of a surprise when, in 1992, radar measurements from satellites showed the volcano was starting to bulge. What's even more startling is that this uplift has continued ever since, at a rate of 1-2cm a year across a region 70km (43 miles) across, making Uturuncu the most rapidly and consistently swelling volcano on the planet.

Uturuncu sits in a class of supervolcanoes that have, in the past, generated titanic, climate-modifying eruptions. At least one scientist monitoring the volcano has speculated that Uturuncu's persistent swelling may be giving us our first glimpse of a new supervolcano in the making, the next eruption of which could have a global impact.

Electrical conductivity measurements of the roots of the volcano have revealed the presence of a magma body deep beneath Uturuncu (magma is more conductive than rock), though its size has not been determined. To explain the amount of uplift, this magma reservoir must be growing at the rate of about 1m³ every second. No-one is suggesting an eruption is imminent – it could be many thousands of years off. But if magma continues to accumulate at the current rate over that time and is ultimately released in a single explosion, a massive amount of sulphur dioxide would be released that would form a veil across the planet, blocking out the Sun. The resulting global freeze could lead to worldwide harvest failure. ■

> *A massive amount of sulphur dioxide would be released, blocking out the Sun*

LIGHTS, CAMERA, ERUPTION!

The Kilauea volcano is the perfect location for BBC *Volcano Live*

To experience molten magma on the move, Hawaii's Kilauea is the world's 'go to' volcano. So it's no surprise that it's the location for BBC *Volcano Live*. Thankfully for presenters Kate Humble and Iain Stewart, eruptions here involve the relatively quiet effusion of lava rather than the explosive ejection of ash and debris. But having first breached the surface in 1983, lava has been pouring out of the volcano, almost non-stop, for an unprecedented three decades. So the chances of the cameras capturing an eruption in action are pretty high.

What makes the eruption at Kilauea different from those at most other volcanoes is the fact that it is not focused at the summit. It is located on the flank nearly 20km (12 miles) east of the peak. Scientists can study the volcano using tilt meters that measure tiny changes in the slope of the ground surface.

More than 50 eruptive episodes have taken place at the flank vent Pu'u 'O'o since 1983, and prior to each an increase in surface tilt was recorded at the summit. A new batch of rising magma causes the area to bulge, generating the tilt. The movements are staggeringly small, typically amounting to just 10-20 microradians. One microradian is just 0.00006 of a degree – an almost imperceptible tilt that can be achieved by placing a 10p piece under a ruler 1.5km (0.9 miles) long.

Before it reaches the surface the rising magma encounters a zone of weakness known as the East Rift Zone, along which it is funnelled horizontally. As the magma pulse decants sideways into the rift zone, the degree of tilt drops suddenly. This tells volcanologists that the magma is on its way to the vent far downslope, where an eruption is therefore imminent.

***Bill McGuire is Professor of Geophysical and Climate Hazards at UCL. His latest book is* Waking The Giant**

Professor Iain Stewart

The BBC science presenter talks to **JV Chamary** about *Volcano Live* and why geology rocks

Focus: Why broadcast a live show?

Iain Stewart: If you take any given day, there are earthquakes, volcanic eruptions and storms around the planet. People don't think about that, just the sudden events that become newsworthy. But they're a daily occurrence – the way the planet behaves, it's breathing. *Volcano Live* will be broadcast over four nights, with myself and Kate Humble at Kilauea in Hawaii, talking about what we can actually see.

F: What's so special about Kilauea?

IS: It's where you can semi-rely on seeing the famous red stuff, the lava. There's lots of active volcanoes but when you get to them, they're often 'turned off' for the day. But Hawaii sits atop a plume of hot rock that's coming up from hundreds of kilometres beneath the Pacific, and this stuff is just oozing out at the surface. It means your average bloke can see some lava, and that's actually very rare. So it tends to be quite a gentle volcano: most of the time the lava is happily spewing out and solidifying and not really causing any trouble.

F: Is there any risk of an eruption?

IS: In general, our understanding of the Earth through things like plate tectonics means we know where to expect 99 per cent of the activity, so we're not envisaging any huge surprises – though it would be nice to get some small ones! But Kilauea can also have an eruptive phase and one of the concerns is what happens if it becomes violent. That's also an emergency situation for the local volcanologists, so they're quite nervous about having a BBC film crew around. We'll want a little bit of action, but none of us wants a full-blown fireworks display and evacuations. Though I dare say if you talk to the director, he'd have a gleam in his eye if he thought about that!

F: Are you filming anywhere else?

IS: There will also be pre-recorded videos from other volcanoes. Volcano science is extremely well-evolved: we can reliably give warning signs of eruptions that are starting sometimes weeks in advance. So I'll be going out with the scientists to show what they can do, and the limitations. Various volcanology groups have also gone off on expeditions with cameras to collect footage for us – apparently it's absolutely spectacular. Tapping into that resource has been a very smart move, because it means we're not reliant on what Hawaii happens to be doing that particular day to get our stories. We know there's some great stuff from around the world that we can bring to the viewer.

F: What excites you about geology?

IS: It's very broad. The common conception of geology is rocks, but if you go into any geology department these days, you're as likely to find an atmospheric chemist, biological oceanographer or physicist, because understanding how the planet works requires all these disciplines. There's now this idea that Earth is a big system, and that system is being perturbed by us humans. So geology's suddenly very relevant.

F: What does your research involve?

IS: I look at geological hazards over the last few thousand years. My main specialism is earthquakes, but I have worked on tsunamis and volcanoes as well. I'm still actively involved in research on Mount Etna in Sicily, for example.

But the bulk of what I do is looking at the effects of these events on human history and past environments. Really big events are beyond historical documents: you have to go out and actually find them in the landscape, in the rocks.

> *"Hawaii sits atop a plume of hot rock that's coming up from hundreds of kilometres beneath the Pacific"*

F: How did you get into geology?

IS: I was interested in geography first and read books about travel and adventure and exploration. Then at school we had a six-week taster of geology and I really enjoyed that. I went to Strathclyde University to do geography, but took geology as an option and was progressively won over.

F: Who influenced you?

IS: At Strathclyde there was a really inspirational professor called Mike Russell. He was an 'economic geologist' – basically mining – but also had a sideline in the origins of life. Mike has probably the most complete chemical explanation for early life, so he works with NASA. He'd rush into the lab and say "Hey, look at this guys!" and tell you about things they'd just been working on, which I now realise were right at the cutting edge. So I can remember that excitement, and also the importance of storytelling. Mike was always full of stories about life as a geologist – in fact I mainly remember his stories, not what he actually taught me!

F: Why do you like presenting?

IS: For me it's the challenge of bringing the active Earth to the viewer. It's part of my life that, in the morning, I look for alerts of volcanoes and earthquakes. And most times it's nothing surprising. But the Earth is dynamic, changeable. I want to bring that big picture to people's minds, and not to see earthquakes and volcanoes as some kind of tragic disaster – it's just the way the planet works. ■

BBC TWO

Iain Stewart co-hosts *Volcano Live* on BBC Two this month. See page 47.

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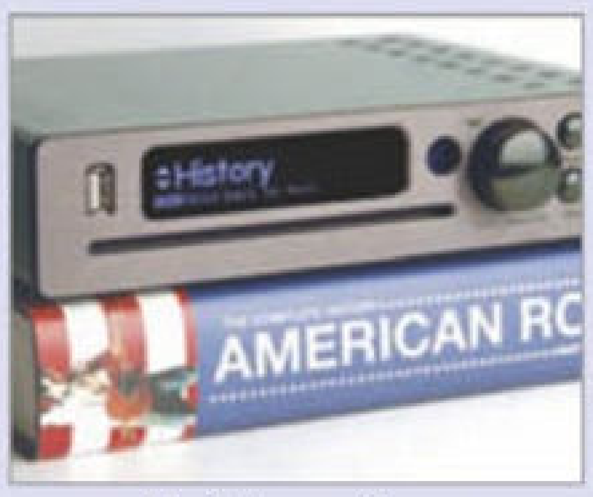

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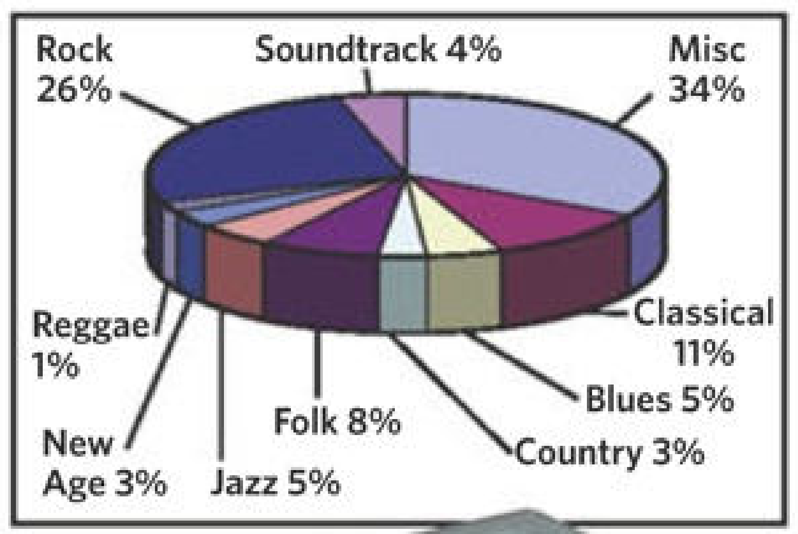

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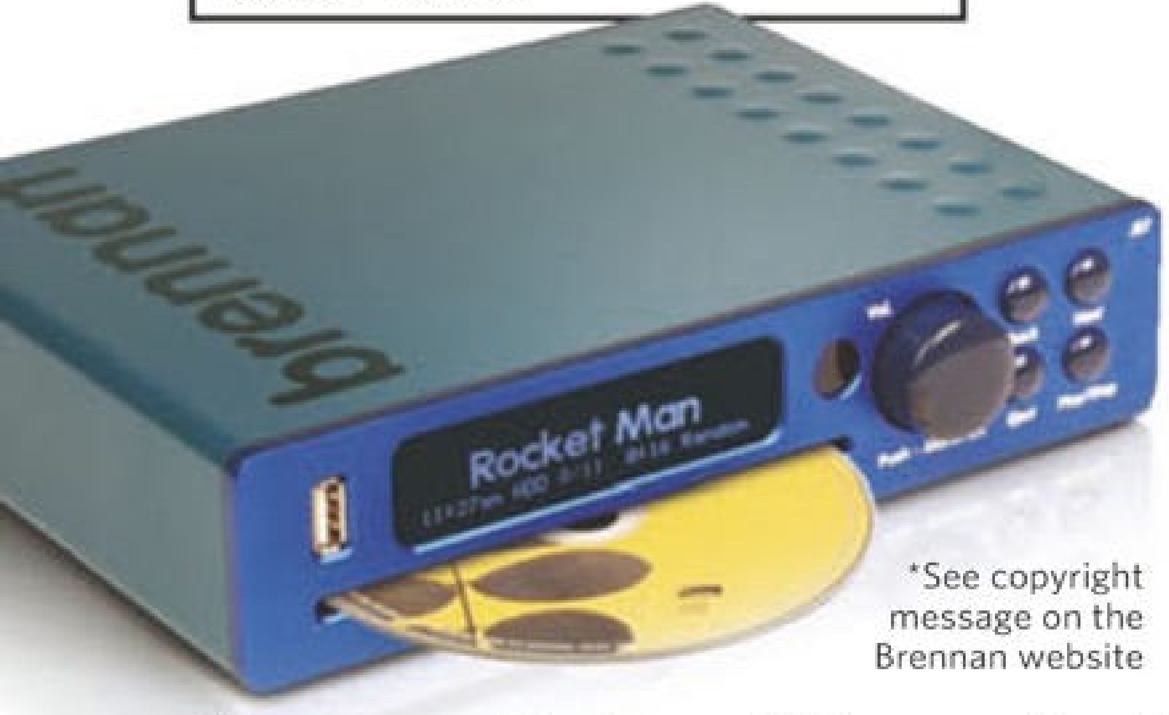

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Martin Brennan

The face behind the Brennan JB7

Martin Brennan has worked with Sir Clive Sinclair and Sir Alan Sugar and has designed over 20 silicon chips in his career. Ever since CDs were invented Martin longed for a CD player that would hold his entire disorganised CD collection.

He wanted something as simple to use as a light switch but at the same time something that would let him find a particular track without leaving his armchair.

In 2006 the record companies said unequivocally that they are happy for you to load your own CDs onto a hard disk but the Advertising Standards Authority have asked us to tell you that it is unlawful to copy material without the permission of the copyright holder.

brennan

THE 10 WORLD CHANGING EXPERIMENTS THAT WILL SHAPE THE FUTURE

Tomorrow's world is being forged in the minds and laboratories of today's scientists. **Dr Paul Parsons** reveals the projects that will revolutionise science

Making predictions about the future is tough. But it's also true that the future starts today, which is why we've scoured the latest research to find the 10 projects that could have the biggest impact on our lives in the coming decades.

Some of these experiments are already up and running. Others are only in the planning stages but stand a strong chance of getting off the ground. On the following pages we present our pick in reverse order of importance. And for more opinions, we asked some of the world's top experts, many of them familiar faces on BBC TV.

Read on to learn about the future and let us know if you agree with our choices. The only genuine certainty is that the future looks bright. ▶

ILLUSTRATION BY MAGICTORCH

10 PLACING SMART MEDICINE IMPLANTS IN THE HUMAN BODY

WHO: Space Biosciences Division, NASA Ames Research Center, California, US
STATUS: Ongoing
COST: Undisclosed

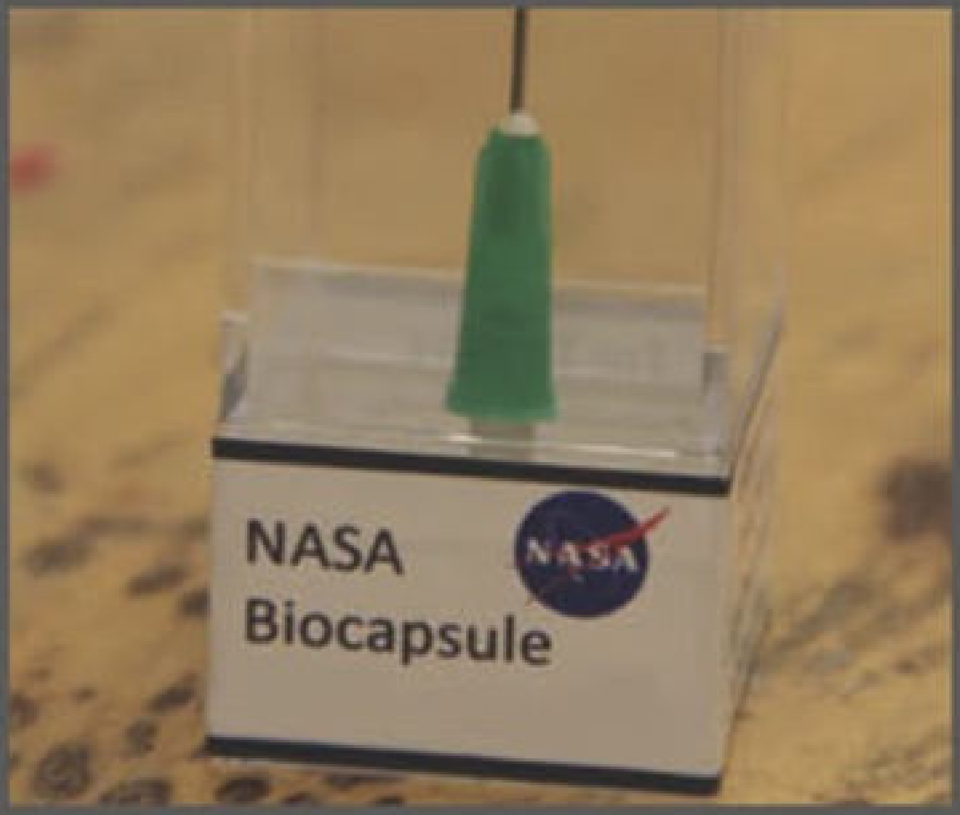
Imagine an intelligent capsule that could be embedded in your body and that could release therapeutic drugs at the first sniff of a medical problem. Such a capsule could save countless lives in those suffering from conditions that require continual, but not necessarily regular, medication, such as diabetes. Just such a device has been developed by researchers at NASA's Ames Research Center, California. They have used carbon nanotubes – tiny cylinders of carbon atoms – to make a small capsule that can be implanted under the skin of astronauts.

The idea is for the capsule to contain biological cells that can react to various threats, such as increased radiation levels (perhaps caused by a solar flare), and release drugs that boost the body's defences. The cells would be engineered, most likely genetically, to produce the drugs in response to certain stimuli.

In the case of radiation protection, the cells could be made to secrete granulocyte colony-stimulating factor (G-CSF) – a drug already given to cancer patients undergoing radiotherapy. Making the capsule from carbon nanotubes gives it a porous structure, allowing the cells inside to thrive, while also enabling the chemicals they give off to flood out.

"The cells inside the capsule secrete therapeutic molecules, and these agents exit the capsule by diffusion across the capsule wall," says Dr David Loftus, who designed the Biocapsule at Ames. The capsule is due to begin animal trials shortly, with human tests following soon after that. If successful, Biocapsules will see service on the International Space Station some time this decade.

Applications on Earth may follow. For instance, filling the capsule with islet cells from the pancreas would enable it to secrete insulin in response to elevated blood sugar levels, providing an automated treatment system for diabetic patients.



Biocapsules could be used to deliver drugs to patients as they're needed

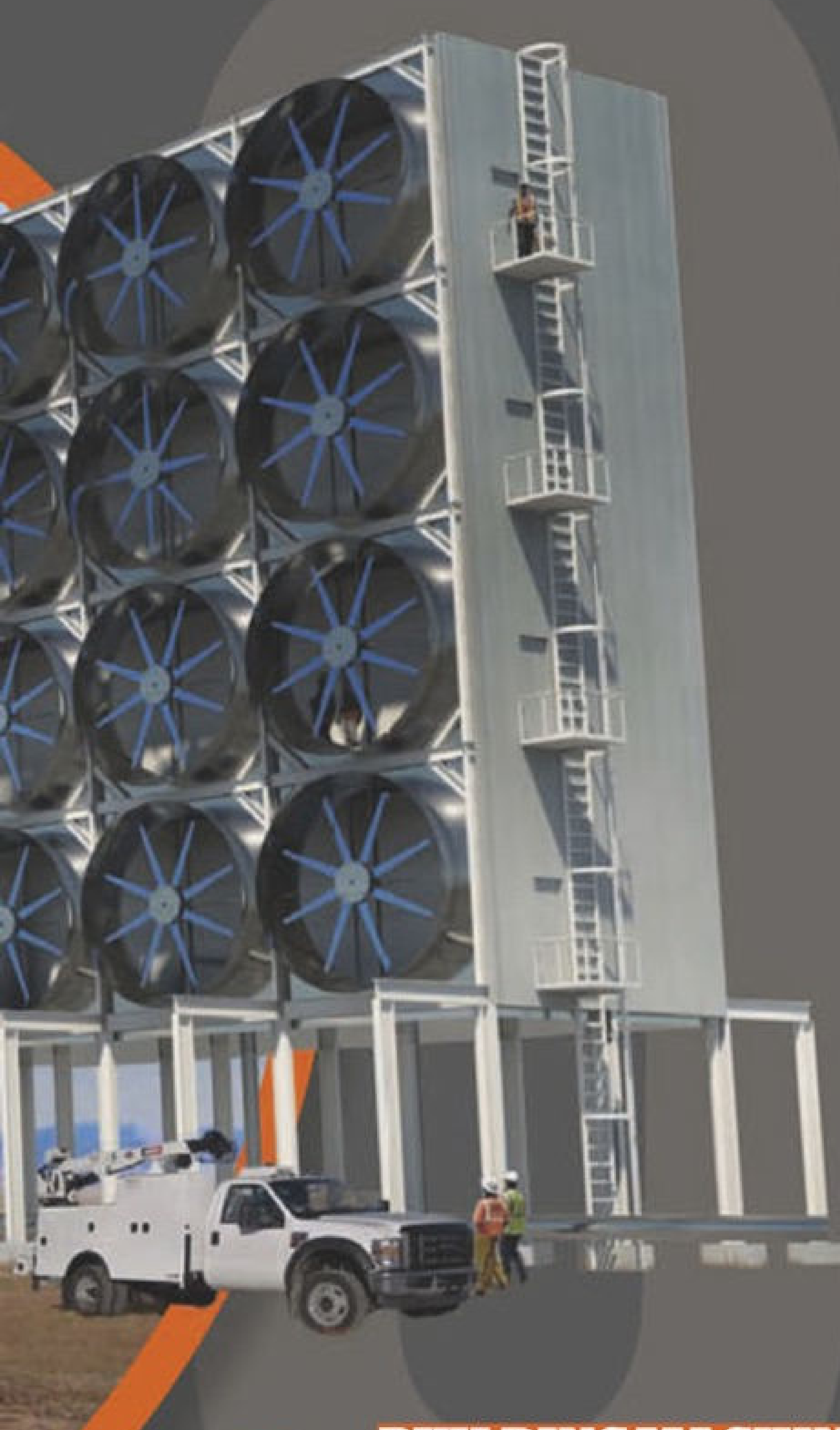
Artist's impression of the Carbon Engineering facility

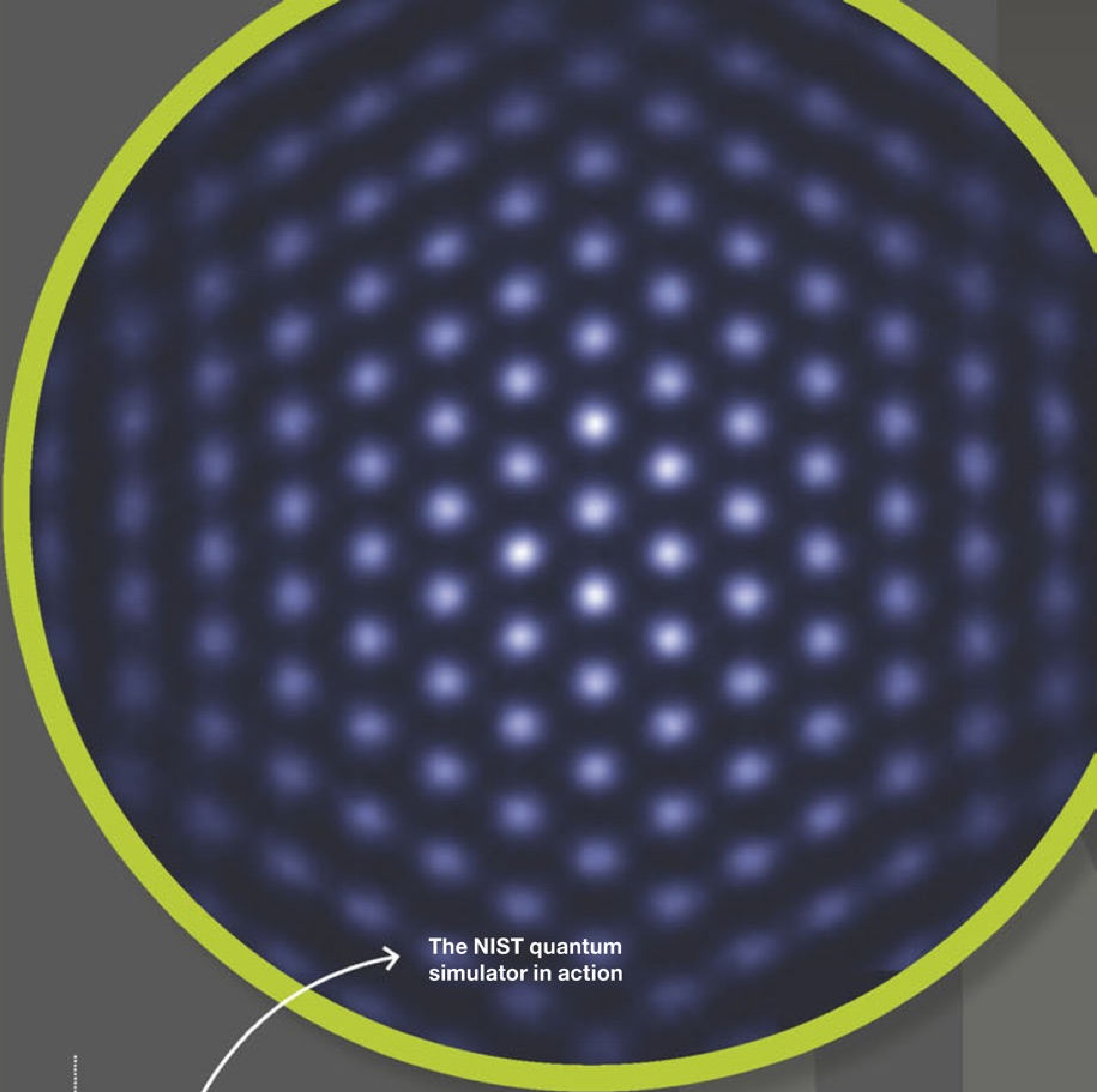
EXPERT CHOICE

Helen Czerski
TV presenter, physicist and oceanographer with a PhD

> "The best things in science are the surprise discoveries that happen when you are looking for something else. My vote for the most important experiment is one that's going on in an unknown lab right now, being done by someone who noticed something unexpected and is just following it up out of curiosity."

GIZMODO, CARBON ENGINEERING, BRITTON/NIST





The NIST quantum simulator in action

9

BUILDING MACHINES TO SUCK CARBON DIOXIDE FROM THE EARTH'S ATMOSPHERE

WHO: Carbon Engineering, Calgary, Canada
STATUS: Initial trials completed in November 2011. Ongoing research
COST: Current commitment to spend approx $6m (£4m)

As governments continue to argue over climate change, and how best to deal with it, you can't help thinking that it might be prudent to have a plan B – a last-ditch strategy to be rolled out should things get really bad.

The principal cause of global warming is carbon dioxide gas, which is churned out by our industry and transportation systems, and which traps heat from the Sun. Canadian firm Carbon Engineering is hoping to geoengineer the climate by chemically extracting the harmful CO_2 from the atmosphere. It's building devices that can suck in air and pass it through a hydroxide solution, from which the CO_2 can be precipitated out as a solid carbonate residue. This residue can then be buried underground (a process known as sequestering) or used for other industrial applications. The company is funded with investment capital provided by Bill Gates and Canadian businessman Murray Edwards.

Last year, Carbon Engineering completed a preliminary test in which carbon was successfully extracted from air by an experimental system for 500 hours. Another experimental run of the same prototype is planned for this summer, with the goal being to clock up several thousand hours' use. Engineers hope this second test run will provide extra information, such as how the device responds to varying weather conditions.

The company hopes to be in a position to be able to work on a commercial pilot scheme in 2013. Each of the finished units – which are expected to resemble the giant cooling tower of a nuclear power station – is expected to remove one million tonnes of CO_2 from the atmosphere per year. Human civilisation gives off around 30 billion tonnes of CO_2 annually, so it would require 30,000 units to completely counteract mankind's influence.

8

DEVELOPING A PRACTICAL SUPERCONDUCTOR

WHO: University of Sydney, Australia and the USA's National Institute of Standards and Technology (NIST) in Boulder, Colorado
STATUS: First results published in *Nature* in April 2012. Research ongoing
COST: Undisclosed

Superconductors could be the future of electricity distribution and storage. These materials have zero electrical resistance – a current in a loop of superconducting wire will continue to circulate forever. They could be used to build lossless cables and batteries for power grids, and for a wealth of other energy-saving applications. But there's a problem. All the superconductors we know of today only work at very low temperatures (less than –163°C). So they would have to be actively cooled, thus wiping out any potential savings.

The race is on to find materials that superconduct at higher temperatures. But it's a problem mired in quantum physics – the tricky laws governing the behaviour of subatomic particles. Solving this problem is just too difficult for ordinary computers. But now, in a major breakthrough, researchers at the University of Sydney and NIST in the US have developed a 'quantum simulator' – a computing device that enables researchers to set up and run simulated interactions between quantum particles and simply read off the results of those interactions. If the interactions are carefully chosen so as to be representative of those that take place inside superconductors, then the device becomes a computer capable of solving the problem.

"In our experiments we produce a well-controlled system whose dynamics are governed by the laws of quantum physics," says Dr Michael J Biercuk, a member of the team undertaking the research at the University of Sydney. "Accordingly, we are able to mimic the behaviour of naturally occurring quantum systems."

In a research report published in the journal *Nature* in April this year, the team described their device, which consists of ions of the metal beryllium arranged in a crystal lattice. They are now investigating how to configure the ions in order to run experiments to mimic processes inside various materials, including superconductors.

A prototype section of the ILC and (inset) the team at Fermilab's Meson Test Beam facility working on the project

7

CREATING ONE MODEL FOR PARTICLE PHYSICS

WHO: International Linear Collider, location to be decided
STATUS: Research and design work underway in preparation for submission of project proposal
COST: $10bn

The standard model of particle physics is currently our best framework for understanding the behaviour of subatomic particles of matter, bringing together all the major particle families and their interactions in one neat package. However, experimental evidence has shown that the standard model doesn't explain extremely high-energy phenomena, such as gravity and the fact that the Universe is expanding at an accelerating rate.

Creating a model that works for all phenomena we'd like to explain in physics would be a momentous breakthrough – comparable with the development of relativity or quantum theory. There will inevitably be momentous real-world applications, although until the details are known it's difficult to speculate exactly what these will be. For example, quantum theory is now crucial to the functioning of lasers, microelectronics, ultra-accurate clocks and unbreakable codes – few of which were even conceivable before the theory was formulated.

So how exactly does reality deviate from the standard model's predictions? You might expect experiments with the Large Hadron Collider, the giant and much-vaunted particle accelerator on the Swiss-French border, to provide the answer. After all, it operates at high energies. But the LHC smashes together the wrong kind of particles – protons. A far better choice would be to collide electrons and positrons together, because the collisions involved are much cleaner, making it easier to pick apart the underlying physics.

"Electron-positron annihilation enables us to ask the questions in a much more controlled environment," explains Professor Barry Barish, of the California Institute of Technology. "We can set and vary the energy in each collision, and study simpler final states."

The trouble is you can't send electrons and positrons around the LHC because they would radiate away all their energy along its circular track – an effect known as 'synchrotron radiation'. The solution is to accelerate them in a straight line, using a so-called 'linear accelerator', or linac. That's why Barish is involved with the International Linear Collider, or ILC, a project to build the world's most powerful linear accelerator.

The initial plans for the 50km-long device are still being drafted by the International Committee for Future Accelerators (ICFA), with a design due to be completed by the end of this year. A location for the project has also yet to be decided, though the team is considering sites in Japan, America, Switzerland and Russia. Assuming that the necessary funding is forthcoming, the ILC could be up and running in approximately a decade.

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EXPERT CHOICE

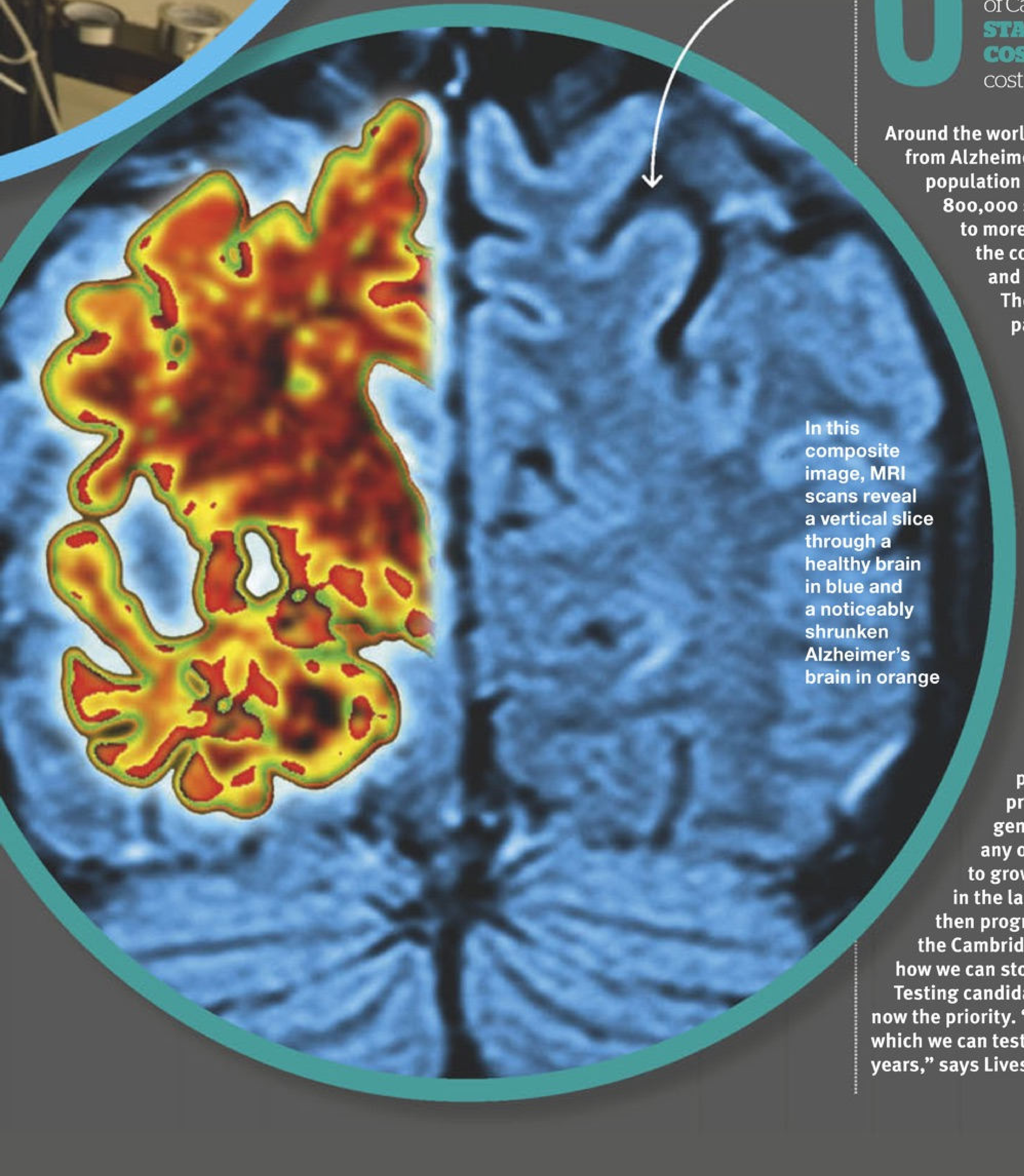
Nina Tandon
Electrical and biomedical engineer
at Columbia University and TED Fellow

"Clusters of cells are being grown on tiny devices, or chips, that mimic human organs to make it easier to test new drugs. Sangeeta Bhatia at MIT has been perfecting liver on chips, Gordana Vunjak-Novakovic at Columbia has been doing the same with hearts, while Donald Ingber at Harvard has developed guts on chips and lungs. If and when these people work together (and they've already collaborated in the past) we'll really be able to put together a human-on-a-chip!"

6

GROWING ALZHEIMER'S IN A PETRI-DISH

WHO: San Diego School of Medicine, University of California and the University of Cambridge, UK
STATUS: Ongoing
COST: £1m for UK research, cost of US research undisclosed



In this composite image, MRI scans reveal a vertical slice through a healthy brain in blue and a noticeably shrunken Alzheimer's brain in orange

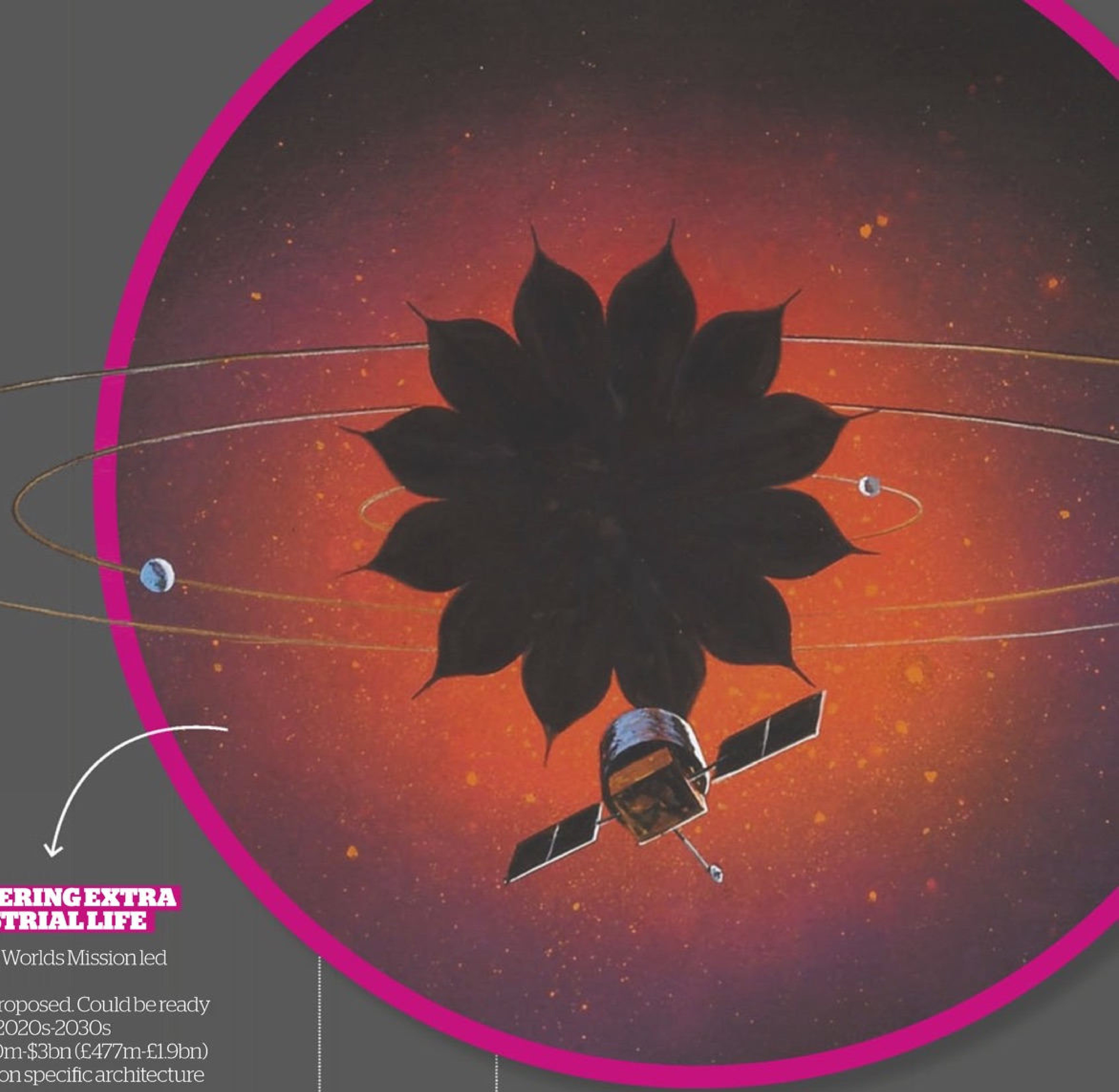
Around the world, over 26 million people now suffer from Alzheimer's disease – that's more than the entire population of Australia. In the UK alone, there are 800,000 suffers. And these figures are expected to more than double by 2050. The root cause of the condition – marked by a loss of memory and cognitive functions – remains unknown. There is no cure and there are very few palliative treatments.

The problem is that you can't just take a sample of infected brain tissue from a living patient to study. Meanwhile, animal models are of limited use because human beings are the only species known to get the disease. That's why the work of two groups of researchers at the universities of Cambridge, UK and California, working independently, could be so important.

They've managed to cultivate brain cells in the lab and then actually watch those cells developing Alzheimer's. This is already yielding some interesting clues about how the disease begins – as a gradual accumulation of small cellular abnormalities.

The teams first took skin cells from patients who were known to be genetically predisposed to the disease. From those they generated stem cells – cells that can grow into any other kind of cell. These were then coaxed to grow into brain cells. "By starting the disease in the lab, it allows us to study how it starts and then progresses in real time," says Dr Rick Livesey of the Cambridge team. "This allows us to understand how we can stop it by developing new drugs."

Testing candidate drugs on the laboratory cell colonies is now the priority. "We are optimistic that we will have drugs which we can test in patients within the next three to five years," says Livesey.



5 DISCOVERING EXTRA TERRESTRIAL LIFE

WHO: New Worlds Mission led by NASA
STATUS: Proposed. Could be ready to fly in the 2020s-2030s
COST: $750m-$3bn (£477m-£1.9bn) depending on specific architecture

Since 1995, when the first planet orbiting a Sun-like star was discovered, over 760 such exoplanets have been found. As the number of known planets grew, so came the realisation that if it was possible to find one sufficiently similar to the Earth, then such a world would be a promising place to look for life. But there was one problem – for all but the very nearest stars, planets orbiting at the same distance as the Earth is from the Sun would be lost in the glare of the parent star's light.

Astrophysicist Professor Webster Cash at the University of Colorado has proposed a 'starshade', a spacecraft that can hover in front of a space telescope and blot out light from the star, enabling the telescope's sensitive instruments to study any planets that might be present. Crucially, this will permit spectroscopy on the light from these planets, enabling astronomers to deduce their chemical make-up.

"This will tell us if there is an atmosphere and its composition," says Cash. "It is also likely to detect water vapour in the atmosphere, and that might indicate oceans. The key biomarker is oxygen – on Earth, this is only present in the atmosphere from the constant replenishing by plants."

Discovering extraterrestrial life would suggest life is relatively common, an important observation for honing theories about how biology first got going on Earth. And that's not to mention the wholesale shift in our outlook. "Just knowing for certain that even very simple microbial life is common in the Universe would change the way we view the night sky," says Cash.

The starshade could either be positioned in front of existing space telescopes or flown as part of a self-contained mission. While the former option is expected to cost in the order of $750m (£477m), the latter would be significantly more.

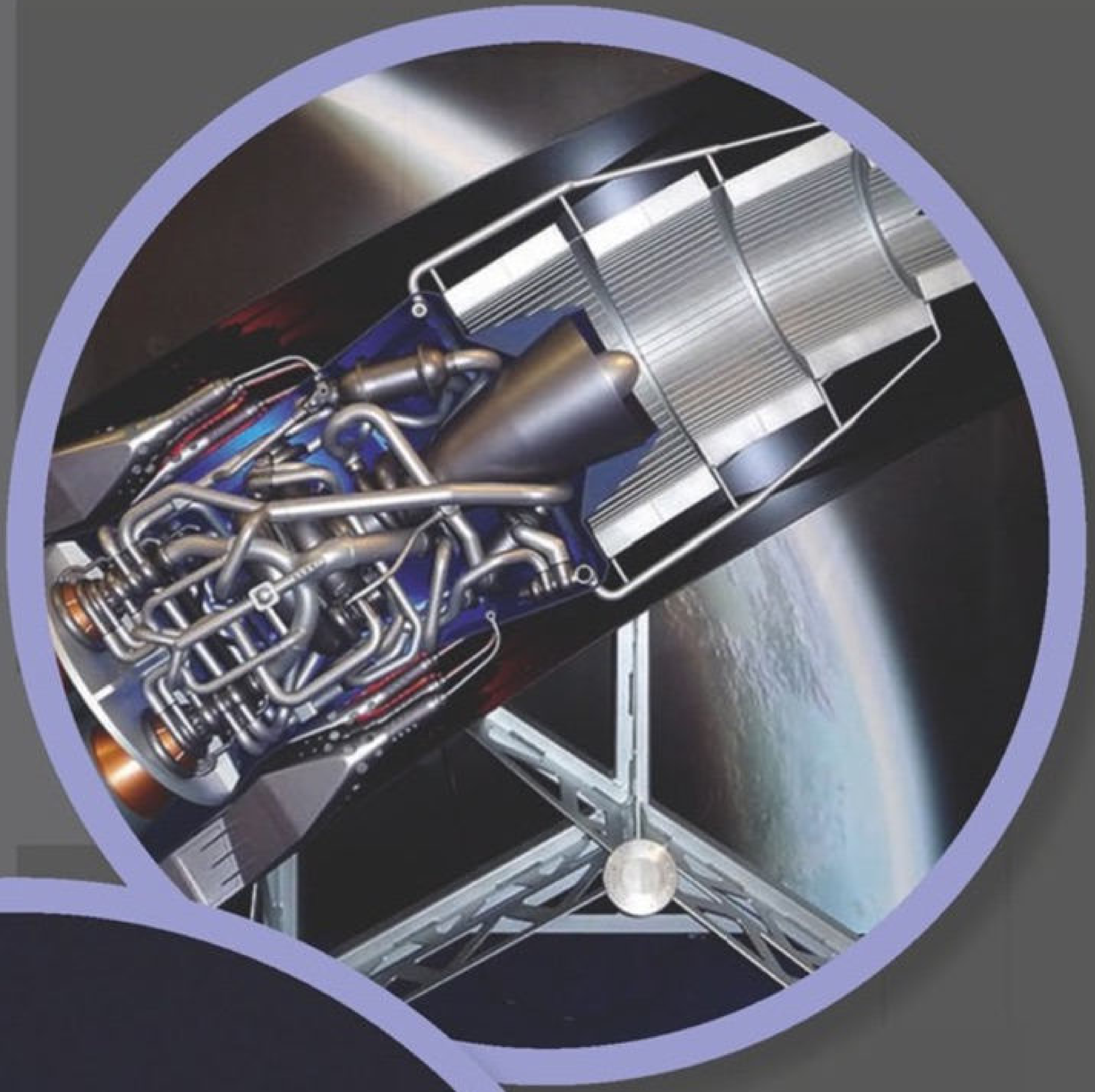
4 DEVELOPING A SINGLE-STAGE-TO-ORBIT SPACEPLANE

WHO: SKYLON project / SABRE engine built by Reaction Engines, Oxford, UK
STATUS: Programme to verify key technologies nearly complete. About to start building the first flight engine, which will power a demonstrator craft
COST: £3bn

Reaching Earth orbit from the planet's surface is a formidable challenge. It means accelerating to speeds of up to 25 times the speed of sound. In the past that's required gigantic multi-stage rockets, one-shot behemoths that had to carry so much fuel they had the explosive potential of a small nuclear weapon. Aside from the danger, their cost was colossal – tens of thousands of dollars per kilo of payload boosted into orbit.

That could all be changing, thanks to research underway on a science park in the idyllic Oxfordshire countryside. A company called Reaction Engines is developing a fully reusable spacecraft that can take off from a runway and fly to orbit without the need for any extra engines or external tanks – a single-stage-to-orbit spaceplane. It could slash the cost of reaching low-Earth orbit by a whopping factor of 50.

NASA, REACTION ENGINES X2



Artist's impressions of SKYLON and (above right) its SABRE engine

At the heart of SKYLON is the revolutionary SABRE – the Synergistic Air-Breathing Rocket Engine. Burning anything requires oxygen. Conventional rockets burn their liquid hydrogen so rapidly they need to carry their own oxygen in liquid form, which is heavy. SABRE, however, extracts the oxygen it needs from the air. It does this using a novel cooling system that plunges incoming air from 1,000°C to –140°C, which compresses it – massively boosting its oxygen density. It does this until it gets to an altitude of 28km (17miles), at which point liquid oxygen takes over.

Designers hope the reduction in launch mass will enable SKYLON to lift payloads of up to 15 tonnes into orbit as a single stage. The company expects the uncrewed spacecraft to be operational by the early 2020s.

EXPERT CHOICE

Jim Al-Khalili

Professor of Physics at the University of Surrey and BBC TV presenter

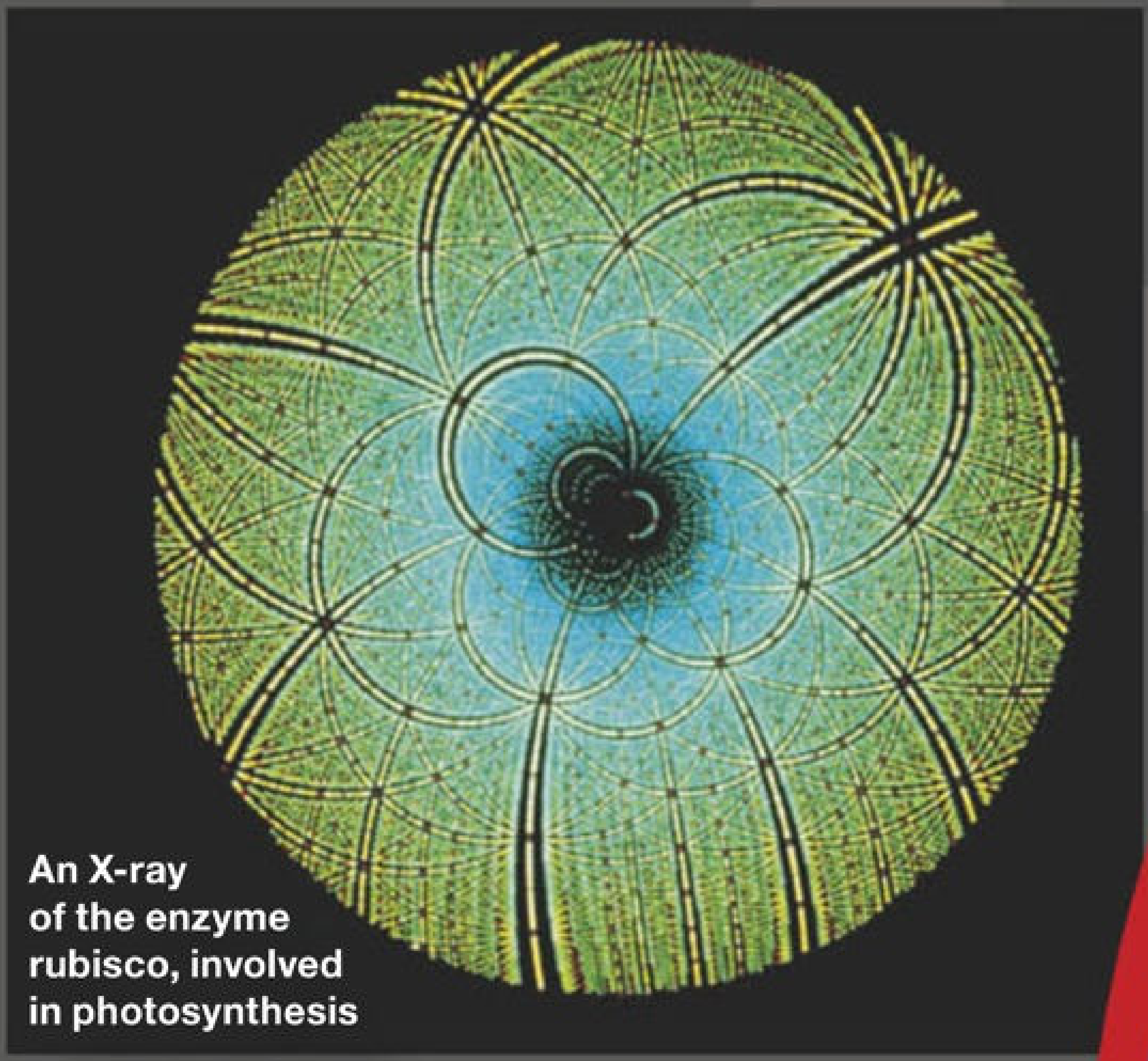
> “My choice is the research aimed at producing fusion energy using laser beams taking place at the National Ignition Facility (NIF), California. It's more exciting than the international fusion project ITER because things there are progressing very fast. Fusion energy (the Holy Grail) may not be as far off in the future as many think.”

3

SUPERCHARGING WHEAT TO IMPROVE YIELDS

WHO: Wheat Yield Consortium, run by the International Maize and Wheat Improvement Center, Mexico
STATUS: Partially funded
COST: Estimated at \$10m (£6.4m) per year for 10 years, followed by a second phase costing similar or less, depending on progress

Boosting wheat yields by 50 per cent will help feed a global population expected to hit 9.6 billion by 2050



An X-ray of the enzyme rubisco, involved in photosynthesis

Feeding the world's seven billion human mouths already requires an agricultural land area the size of South America. And with the population set to grow a further 2.6 billion by 2050, scientists are keen to find more efficient ways of producing food.

Experts from the Wheat Yield Consortium (WYC) believe one way to avert this potential crisis is by 'supercharging' wheat – tweaking the plant's biochemistry to significantly increase the quantity of edible wheat produced. Their aim is to raise wheat yields by 50 per cent within the next 25 years. But how?

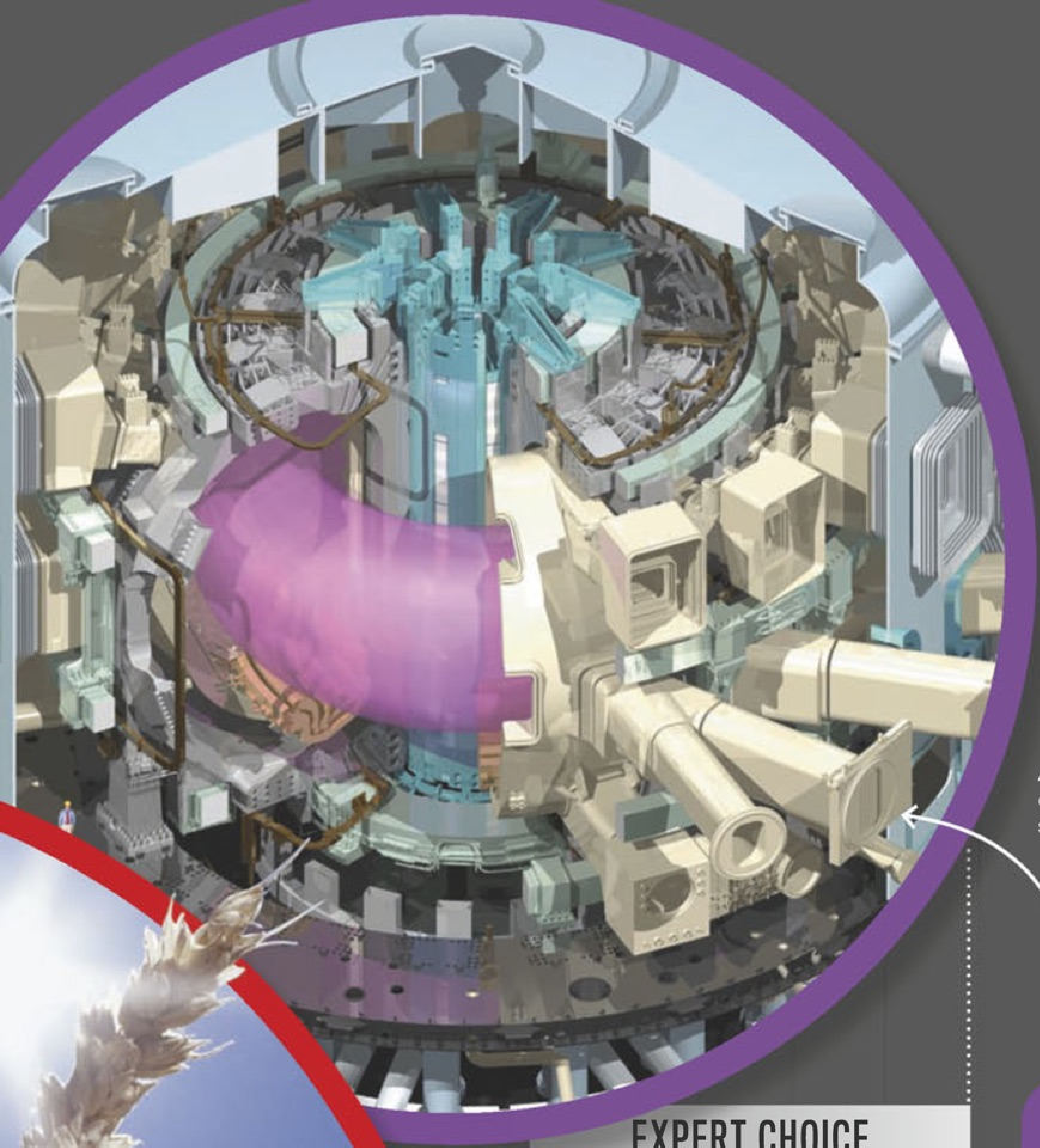
Key to their plan is improving the efficiency of photosynthesis, which is currently the weak part of the chain. Photosynthesis is a series of processes whereby a plant takes in water, sunlight and carbon dioxide from the atmosphere, and uses them to make carbohydrate food, plus oxygen.

"We are focusing mostly on improving the main enzyme of photosynthesis, rubisco, which is quite inefficient – probably because it evolved at a time when the CO_2 and O_2 levels of Earth's atmosphere were quite different," says WYC wheat physiologist Dr Matthew Reynolds.

The plan is to boost photosynthesis's powers of energy production using a combination of genetic modification and traditional cross-pollination – as well as developing biological mechanisms that will concentrate CO_2 from the atmosphere, giving the process extra raw material to work with.

The project is now seeking full funding, but some trials have already begun at WYC's research field station in Mexico's Sonora Desert.

GETTY, ITER ORGANISATION



Artist's impression of the 'tokamak' section of the ITER

EXPERT CHOICE

Marcus du Sautoy
Professor of Mathematics, University of Oxford and BBC TV presenter

> "Several experiments across the planet have the potential in the next few years to redefine what we mean by a kilogramme. The kilo is defined as the mass of a lump of metal, cast in 1879 and kept near Paris, which is thought to be degrading. These measurements should correspond to something universal."

2

DEVELOPING A SAFE AND ABUNDANT SOURCE OF NUCLEAR ENERGY

WHO: International Thermonuclear Experimental Reactor (ITER), France
STATUS: Under construction – due to be operational in 2020
COST: €13bn (£10bn)

In 1956, the UK fired up the world's first nuclear power station, at Calder Hall in Cumbria. Nuclear energy was hailed as a plentiful source of energy for the future. Since then, however, incidents at Three Mile Island, Chernobyl and Fukushima have made it clear that this power source comes at a cost.

An experiment due to get underway within the next decade could change that, furnishing us with a nuclear power source that's safe, and that is capable of providing us with energy for thousands of years. The project is called ITER.

All commercial reactors today exploit nuclear fission, a process whereby uranium atomic nuclei are bombarded by neutron particles, causing them to split apart and liberate energy – along with more neutrons, which repeat the process, setting up a chain reaction. It's not ideal: the uranium fuel must be mined and processed, the chain reaction has to be constantly kept from running away, and the fission fragments remain radioactive for hundreds of thousands of years, creating a waste disposal problem.

ITER, on the other hand, will be a nuclear fusion reactor. It will work by bonding together deuterium and tritium (atoms of hydrogen with extra neutron particles).

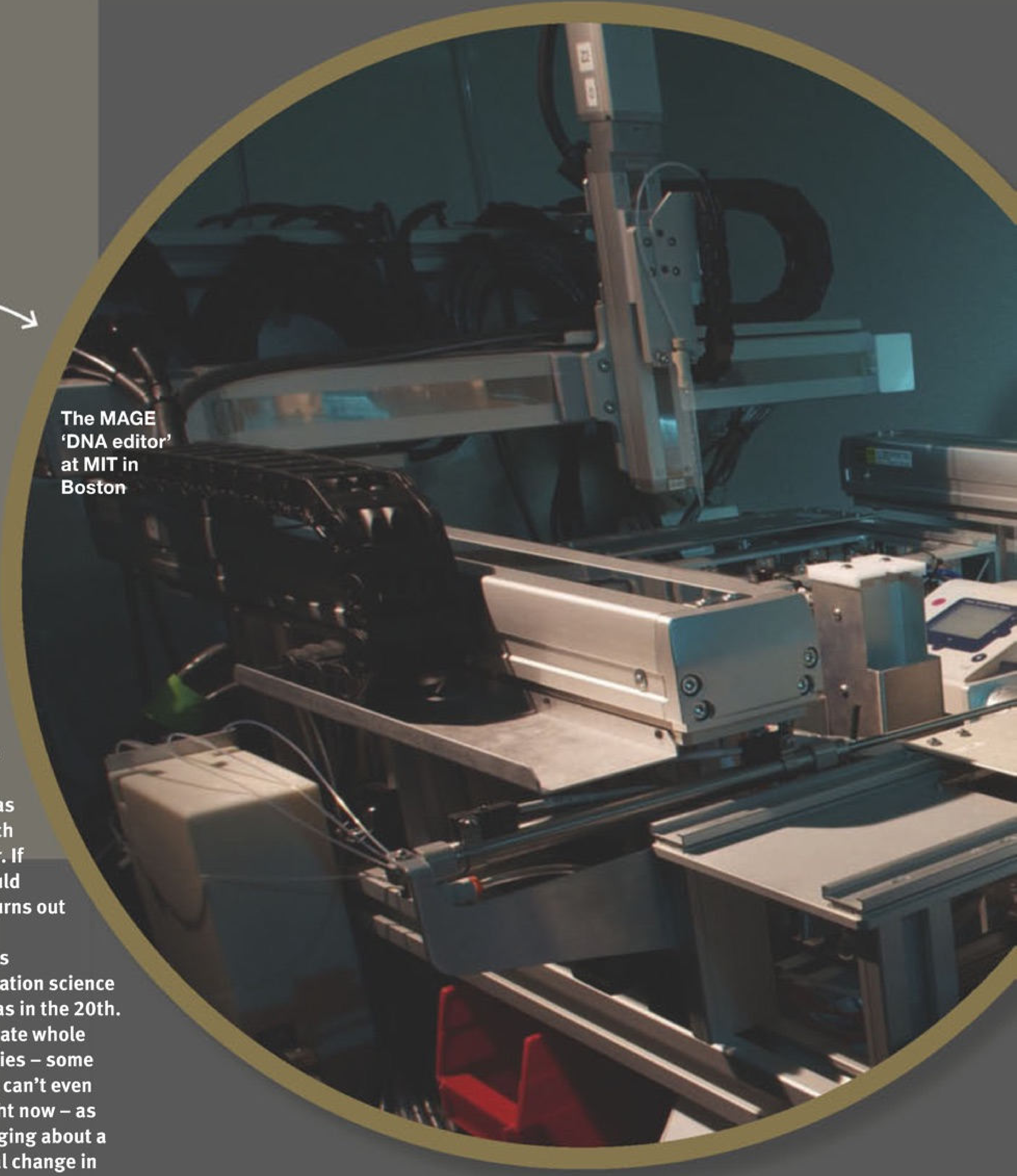
"Fusion is safe, there is no chain reaction," says ITER team member Michel Claessens. "Fusion reactors produce no long-life radioactive waste, and there is plenty of fuel available – deuterium is fairly abundant in seawater and tritium can easily be produced from lithium."

Fusion is the power source that makes the Sun shine. The problem researchers must overcome before they can harness it is containing the superheated fuel – at temperatures of up to 150 million degrees Centigrade. ITER will attempt to solve this using magnetic fields to trap the fuel inside a ring-shaped containment vessel, known as a tokamak.

1

BUILDING A MACHINE THAT CAN EDIT HUMAN DNA

WHO: Massachusetts Institute of Technology and Harvard University, Massachusetts, US
STATUS: Ongoing
COST: Undisclosed



The MAGE 'DNA editor' at MIT in Boston

A team in Massachusetts has built a machine capable of editing DNA – much like the 'cut and paste' facility of computer word processing applications. It could mean doctors will soon have the ability to edit out the DNA letters coding for heritable diseases in the human genome, as well as rendering the body immune to harmful viruses such as HIV and flu. The benefits don't end there, either. If the DNA being edited resides in a bacterium, it could turn the microorganism into a tiny factory that churns out drugs, or even new fuels.

The information science of the genome will be as transformational in the 21st century as the information science of silicon was in the 20th. It will generate whole new industries – some of which we can't even imagine right now – as well as bringing about a fundamental change in the way we treat disease.

The guts of MAGE – a network of vials and tubes

The machine built in Massachusetts that goes by the rather unassuming name of MAGE (short for Multiplex Automated Genome Engineering) is a significant development in this nascent branch of science. Essentially a network of flasks, tubes, pumps and control instruments, it works by hijacking the process of DNA replication – which occurs when biological cells naturally make copies of themselves. Rather than letting the cells make a perfect copy, the machine intervenes to swap small sequences of letters known as 'codons' for new codons of synthetic DNA.

A codon is composed of three DNA letters. Each letter represents a particular 'base' chemical (labelled either A, G, T or C) and each codon encodes a specific type of amino acid. When bolted together, the sequence of amino acids creates a protein molecule that performs a certain function in the cell.

Much of the DNA language is redundant, however – several different codons can represent the same amino acid. In a recent experiment to demonstrate the technique, MAGE was able to replace all the TAG codons in *E.coli* with TAA codons. Both of these codons produce the same amino acid and so they serve the same function.

If such redundant codons are now reprogrammed to build amino acids not normally found in nature, then cells can be turned into chemical factories which are able to produce new compounds on demand. For instance, LS9, a biofuel company in San Francisco co-founded by Professor George Church of Harvard University, the same geneticist who led the TAG replacement study, is using engineered *E.coli* to produce sustainable fuels.

"The first practical applications are already happening, in the form of maximising the production of valuable chemicals in bacteria," says Church. "The next set of MAGE applications are aimed at making multivirus-resistant industrial cells. We expect to have demos of these going within a year."

Church's team is now turning its attention to applying the MAGE technology to human cells – which could bring radical benefits to the human condition. Imagine being able to simply edit out the genes responsible for heritable conditions such as Down's syndrome and Huntington's disease. Or what about protecting your cells with a 'genetic firewall' that makes them immune to viruses? Influenza, hepatitis and HIV would cease to be the killer illnesses they are today. Church is quite open to the idea of modifying the genetic code of embryos to produce virus-resistant babies.

The researchers are currently using MAGE to modify human stem cells. Their plan is to edit the cells' genetic code so as to introduce mutations in a controlled way, giving insights on which mutations cause disease. ■

OVER TO YOU!

Are these experiments in the right order? Have we missed something completely? Let us know your opinion. Email post@sciencefocus.com and join the conversation on Twitter. Tweet @sciencefocus and include the hashtag #10experiments

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AGE: 28
OCCUPATION: ELECTRICAL ENGINEER
STATUS: SINGLE
HOBBIES: MUSIC PRODUCTION, BASKETBAL
FAVOURITE MOVIE: ALIEN

MUTUAL FRIEND: STACEY BLACK

MUTUAL FRIEND:

Your phone's camera could soon be layering people's social information on to its screen in real time

FRIENDS REINVENTED

As the concept of social networking turns 50, how will sites like Facebook evolve over the next decade? **Christopher Mims** gets connected

Before the US Department of Defense had even begun constructing the computer network that would become the internet, some had already recognised that it could be used for human social interaction. In 1962, computer scientist JCR Licklider of the Massachusetts Institute of Technology (MIT) proposed a 'Galactic Network' of people and machines that very much resembles the modern internet.

Licklider's vision has since been realised, so what do today's researchers – scientists and entrepreneurs who are building new ways to interact online – predict for tomorrow?

To work out what's next, you need to study the current trends in online networking. The biggest advance in social networks has been the transition from PCs to mobiles. In 2010, venture capitalist Mary Meeker – once dubbed 'the Queen of the Net' – projected that, over the next five years, the number of people visiting the web via phones would eclipse those accessing it on a PC.

As more of us share personal information online, digital forms of interaction will overflow into the physical world with the use of mobile technology. According to Professor Alex Halavais, of Arizona State University, an expert on the social dimensions of the web and president of the Association of Internet Researchers, we'll soon be sharing our digital profile in the real world. Someone would just have to hold up their phone's camera to view information on you. "Imagine going down a street and seeing just how many degrees of separation there are between you and a stranger," says Halavais.

This use of mobile technology means that the full potential of the famous 'six degrees of separation' theory could finally be harnessed. It states that each person on Earth is connected to everyone else by no more than six 'hops' between mutual friends. These weak connections allow some people to have thousands of Facebook 'friends'. And those connections can be useful: one study demonstrated that the best way to find a job was through second-degree connections – friends of friends.

This phenomenon was detailed in a landmark paper entitled 'The Strength Of Weak Ties' by Stanford University sociologist Mark Granovetter. His observation was simple: while we're likely to already know what friends know, friends of friends – our ▸

GETTY, ILLUSTRATION BY THE WHITE BALANCE

The shape of things to come: Google's Project Glass could overlay social networking data on your field of view

▶ acquaintances – are likely to know things we don't, such as who's hiring.

"Four degrees isn't that much in a city," says Halavais, who believes that knowing how we're connected to someone in advance makes it more likely that we'd strike up an actual conversation. Increasingly, we're meeting people in real life whom we've already gotten to know online, so making those encounters a little less accidental would simply be an extension of that experience.

Augmented reality

This migration of your information to the real world is set to become seamless. Google's Project Glass is a heads-up display that layers information over your field of view, creating an 'augmented reality'. Project Glass appears to be controlled via a touchpad on the glasses' right arm, where a camera and battery are housed. While the glasses are still in the experimental stage, the project's engineers have already demonstrated the ability to snap photos using the small camera embedded in the frame and share them on the social network Google+ with a barley noticeable gesture of the head.

With Project Glass you could instantly identify anyone around you through face recognition software, then bring up all of their publicly available information. This would enable a level of real-world social ability previously only seen online. A seemingly far-off vision of social networking, it is closer than you think: "I have some hopes of maybe getting it out some time next year," said Google co-founder Sergey Brin in May.

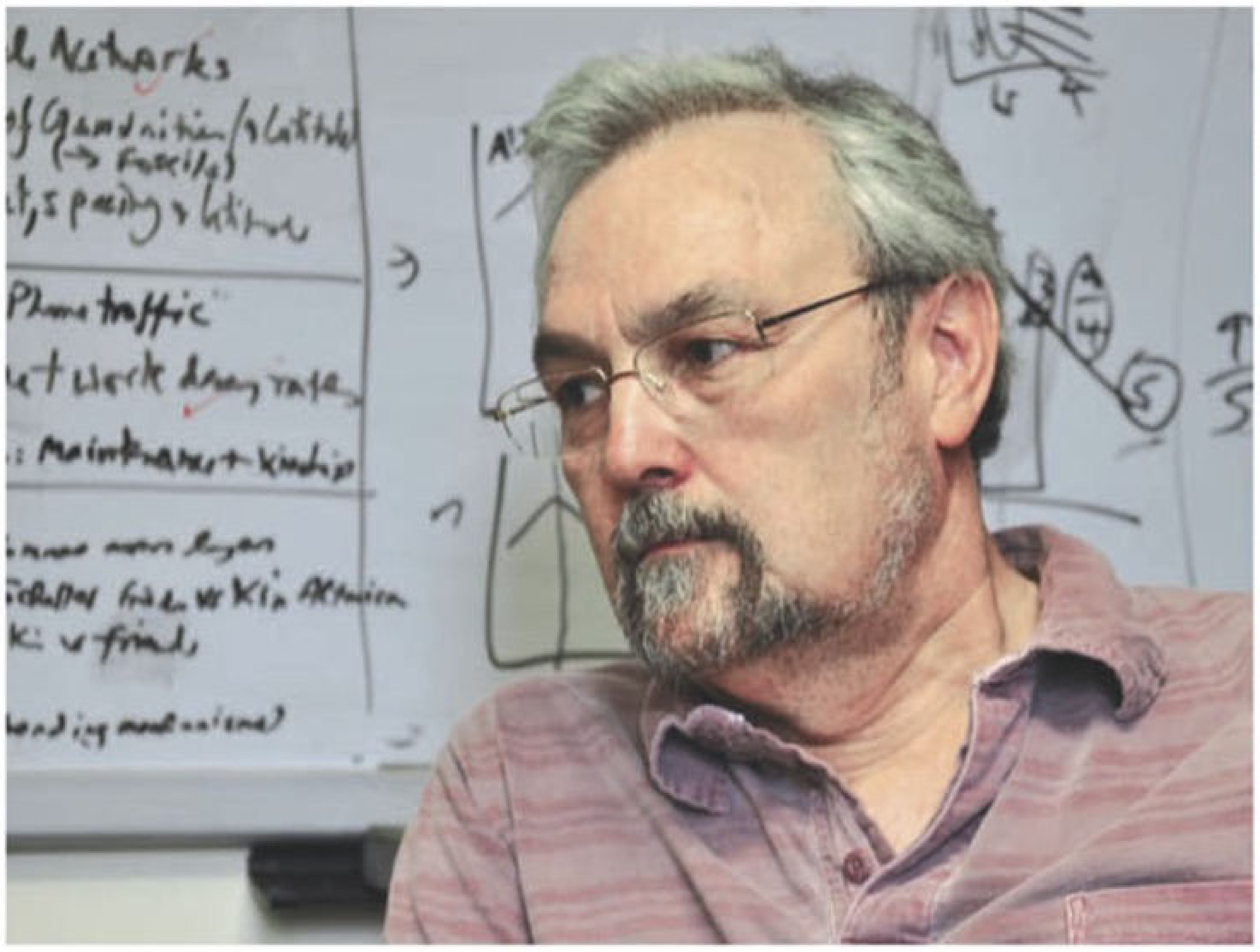
So what's the end result of enhancing the physical world with networks from the digital domain? As personal information becomes as easy to access as just looking at someone, it will become harder for us to lie about who we truly are. Facebook CEO Mark Zuckerberg proposed that "The days of you having a different image for your work friends or co-workers and for the other people you know will probably come to an end pretty quickly."

> *"Project Glass could enable you to identify anyone around you through face-recognition software"*

Before we start giving up unprecedented amounts of information about ourselves, however, the traditional model of social networks – in which a single company controls all of your data – will be eclipsed by something else. If users have confidence that they have complete control over their data, there's no limit to what they might record and selectively share.

Over the next few years, online stores of information will be the first stop for everything we record about ourselves. Such a secure repository of your own data is known as a 'personal data locker', and it will store all those location check-ins, status updates and holiday photos, plus identifying information like our home address and health records.

The companies that provide those lockers will have a financial incentive to protect the privacy of your social data. "Data in itself is infinitely replicable, so ownership is an elusive concept," says Jason Cavnar, co-founder of Singly, a personal data locker startup company. He thinks that people will soon be less concerned about privacy and more about what they can get in exchange from firms using personal data.



Evolutionary psychologist Prof Robin Dunbar believes the human brain can only handle a maximum of 150 relationships

CORBIS, ALAMY, STEPHEN GUERIN/REDFISH GROUP, THINKSTOCK, CARDIFF UNIVERSITY

Privacy concerns aside, how might social networks themselves evolve in the future? There has been a recent trend away from do-it-all services like Facebook, and towards networks designed for specific activities and smaller groups – such as Microsoft's So.cl, which is targeted at students who want to share and comment on interesting search results.

"There has certainly been a shift to more private and personal networks – like Pair and Nextdoor – but we don't feel that networks like Facebook and Twitter will disappear," says Dave Morin, co-founder of Path, a social network designed for mobiles that limits your connections to 150 people.

Path is built on a scientific premise: according to evolutionary psychologist Robin Dunbar of Oxford University, our core social circle only consists of around 150 people, known as Dunbar's Number. "Professor Dunbar has long suggested that 150 is the maximum number of social relationships that the human brain can sustain at any given time," Morin explains. He adds that this limit not only helps privacy, it also keeps you connected to the people who matter most. "These are the people we trust and whom we consider to be the most important and valued in our lives."

Networked science

Indeed, recently published research gives us a glimpse of how science may shape future services. The studies reveal not only that technology will become much better at predicting what we will buy, but also where we'll go and who we'll meet.

Studies by Tingshao Zhu and colleagues at the Graduate University of Chinese Academy of Sciences in Beijing found that our activity online proves an excellent guide to our real-world personalities. Psychologists have long used questionnaires to gauge our so-called Big Five personality traits, which are conscientiousness, extraversion, agreeableness, neuroticism ▶

SOCIAL SCIENCE

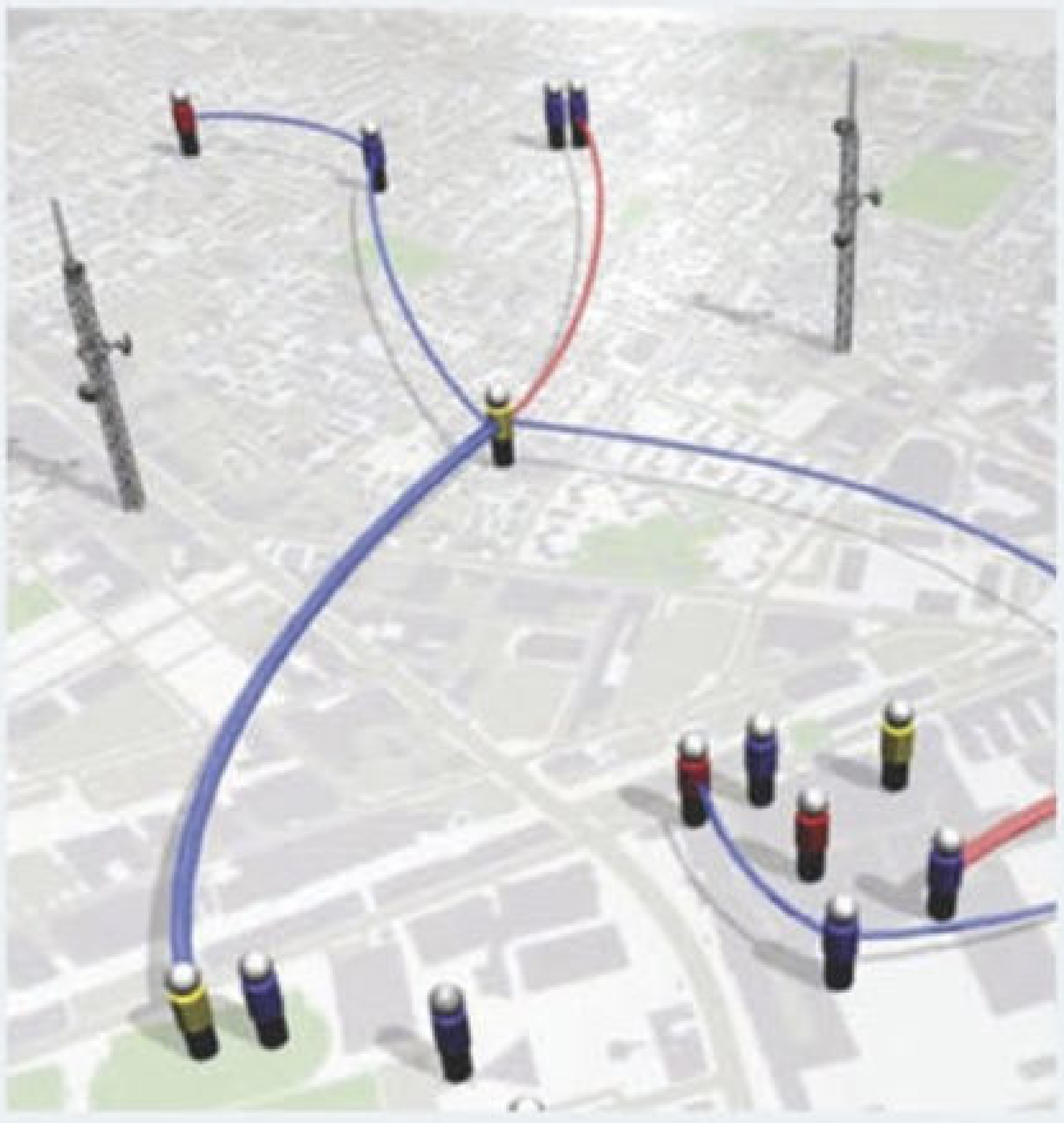
Scientists are using online networks to study human interaction

THE POWER OF INFLUENCE

Influential people – those with the most connections to other individuals – tend to catch both ideas and diseases before anyone else. It means that they act as a system for tracking trends. One way to identify 'influencers' is to map every single connection in a network, such as a city. But this is mathematically challenging, so social scientists Nicholas Christakis and James Fowler took a simpler approach: they asked 100 students to name a friend, predicting that common friends were more likely to be influencers. They found that those who'd been named caught the 2009 flu bug two to six weeks earlier than people who were randomly selected, suggesting they were indeed influencers. Services such as Klout measure online popularity to identify people who are more likely to persuade others to follow a link or buy a product, so 'influence scores' could soon be incorporated into social networks.

PREDICTING YOUR FRIENDS

Using nothing but data from the mobile phones of undergraduates, researchers at MIT were able to predict an individual's friends with 95 per cent accuracy. They did this with only two pieces of data: who a person called and the distance between phones, as measured by location services. Mobile operators already have this data, which means that they could easily sell information about the structure of our social networks to marketing firms. The MIT researchers also found that it's possible to predict who's unhappy at work: people who made frequent calls to friends during business hours reported the lowest job satisfaction. In a future where we have the confidence to share more information with online services, mining this data could allow analysts to make all sorts of predictions, from where a virus will spread to who's most likely to commit a crime.



MAKING MONEY ONLINE

As services like Facebook become globally popular, people in the developing world will invent new ways to exploit social technology. Dr Nathan Eagle is a researcher at Harvard University and co-founder of Jana, a firm that helps companies gather data on the mobile web in developing countries. He engineers computational tools to explore how data from studying human behaviour can be used for social good. In Indonesia, for instance, local merchants in Jakarta have an ingenious way to promote their goods: they take a photo of something they want to sell – such as a kettle – then tag it on Facebook with the name of everyone in their address book. Facebook then notifies their 'friends' that they've been tagged in a photo, showing them what's on sale. This shows that, in future, selling our personal data won't be the only way that people will profit from social networks.

▶ and openness to experience. The researchers asked 200 students to complete an online Big Five questionnaire, as well as looking at how they used their accounts on RenRen, a Chinese equivalent of Facebook. Factors included how often they posted and whether posts were angry, funny, surprising or moving.

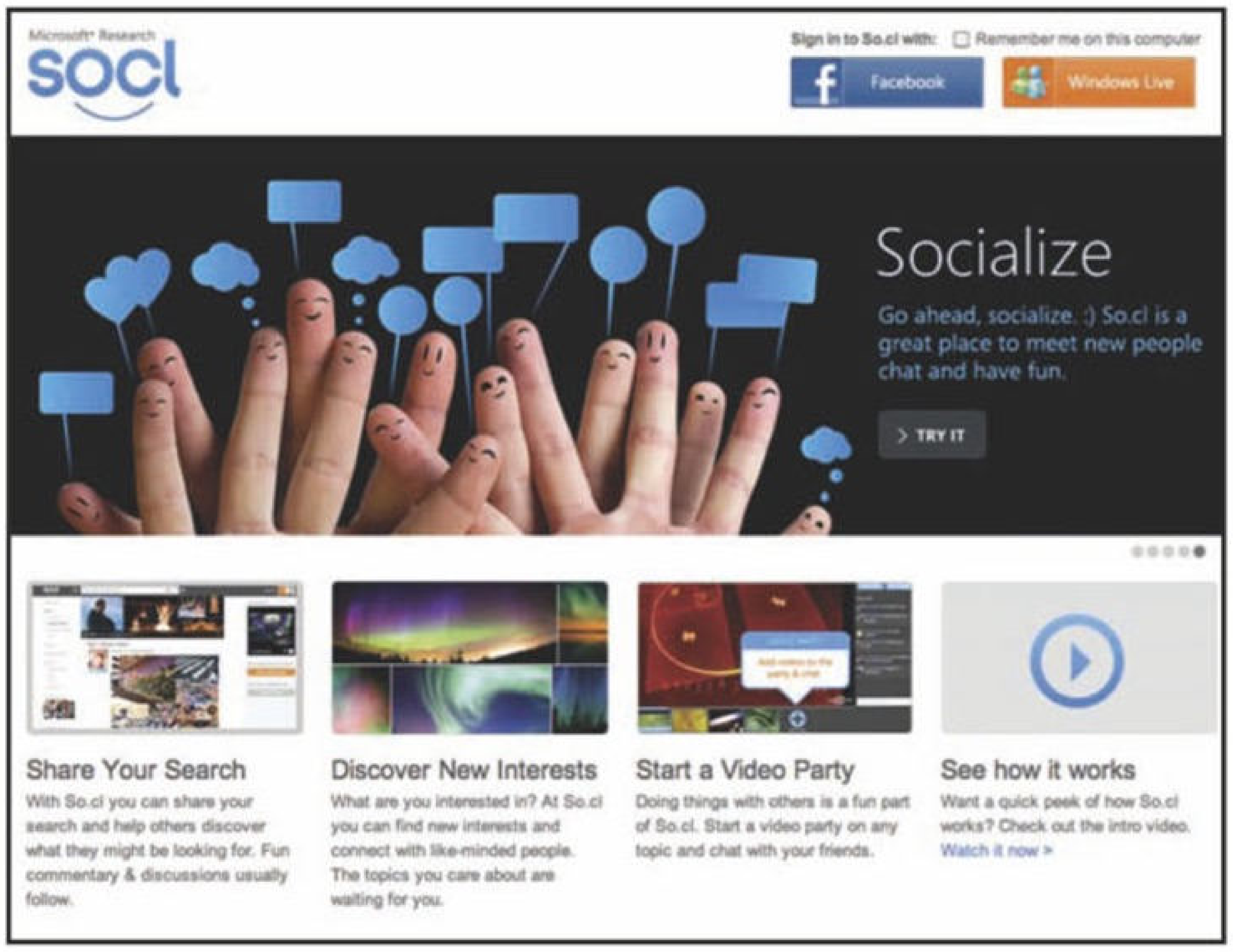
The research found that there was indeed a match between personality type and how they used RenRen. Outgoing people used more emoticons and had more friends, while conscientious types were more likely to ask for help, such as getting directions or finding an email address. The researchers say that the system could be used for the online treatment of mental illness, as well as helping service providers tailor their offerings. Online shopping recommendations will be more accurate if they're based, at least in part, on your personality.

Researchers are also finding that coupling social networks with mobile technology has wide-ranging possibilities. The next step is to automate the gathering of social and location data that our phones provide, a technology known as 'reality mining'.

Professor Sandy Pentland, director of MIT's Human Dynamics Laboratory points out that things like photos and status updates present people in a controlled way, and don't reveal much about a person. "You are what you *do*, not what you *say* you do – the stuff you put on Facebook or Google+ is ephemera – it's advertising," says Pentland. "But where you actually spend time and what you buy matters. That's who you really are, and we're going to start recording that."

What makes reality mining possible is the always-on nature of our mobiles. Combine details from an address book with knowing where your contacts are, and you'll end up with an almost spooky level of insight into user behaviour. This provides information that you might not otherwise give away.

To demonstrate how our personal data is already being used to better understand human behaviour, Pentland's students have used always-on tracking on their smartphones and social networks to determine how students catch the flu virus as it sweeps across the northern hemisphere every year. By examining self-reported health status and activity patterns,



Socialize

Go ahead, socialize. :) So.cl is a great place to meet new people chat and have fun.

Share Your Search

With So.cl you can share your search and help others discover what they might be looking for. Fun commentary & discussions usually follow.

Discover New Interests

What are you interested in? At So.cl you can find new interests and connect with like-minded people. The topics you care about are waiting for you.

Start a Video Party

Doing things with others is a fun part of So.cl. Start a video party on any topic and chat with your friends.

See how it works

Want a quick peek of how So.cl works? Check out the intro video. Watch it now >

Microsoft's social network So.cl reflects a growing trend in new networks to focus on small communities, instead of trying to compete with global networks like Facebook

Q&A: SANDY PENTLAND

The director of MIT's Human Dynamics Laboratory on the future usage of your online data

As more of our data finds its way online, sites like Facebook have come under increasing pressure over privacy policies

How will we protect privacy?

I've been running meetings with the World Economic Forum. It includes all the Googles and Microsofts of the world, the EU Justice Commission and the US Federal Trade Commission (FTC). Those discussions have resulted in fundamental changes in privacy policy all over the world. The results can be seen, for example, in the new declaration by Viviane Reding, vice president of the European Commission, about personal data rights being a basic human right, while the FTC just came out with a data 'bill of rights'. They establish your rights to see, know and control data about yourself.

Could we sell our personal data?

I call this 'the new deal on data' – you control the data, not the company. Policymakers did something right here because, if you can control your data, then companies have to pay you for it. Also, what people want can shape how it's used. The World Economic Forum did a report called Rethinking Personal Data. The idea is that all this new data about people could be an incredible curse or an incredible benefit. But currently it's all locked up, and nobody knows who owns and controls it. In the EU and US, what's come out is that you can control data about yourself. That makes it something you can leverage.

How will our data be physically secure?

The preferred method is 'trust networks'. When banks transfer money between themselves, they're transferring millions of dollars over the same digital nets that we use. The way they do it is a trust network. It's a special type of communications protocol that combines law and computer code: the trust networks are actually parts of legal contracts. So the computers are signing contracts for us. It says 'I offer to transfer 100 million dollars' and that establishes a contract that also specifies what happens if the $100 million doesn't show up. It says who pays and how they will arbitrate it. It's a *distributed* network and that makes them all watch out for each other.

REUTERS, PRESS ASSOCIATION

Facebook founder Mark Zuckerberg believes we will find it hard to maintain different identities across multiple networks

which show who got sick and when, Pentland was able to trace the spread of the 2009 flu through the student body. Epidemiologists could use such data to predict where – and who – to avoid in order to prevent infection in the event of a real disease outbreak.

Pin-point interactions

Another research project points to an even more outlandish vision of future social networks. From March to August 2010, computer scientists at the University of Illinois tracked 79 students on campus through the wireless Wi-Fi and Bluetooth connections on their smartphones. The students' locations were plotted by their use of Wi-Fi access points around the campus while Bluetooth, which works over a shorter range of just 10m, tracked interactions between a phone and users nearby.

The data was employed to design a system called Jyotish – the Hindu word for astrology. It's aptly named because the data allowed the scientists, led by Long Vu of the department of computer science, to make predictions with what they describe as "high accuracy". Not just where the users went but who they were likely to meet and, with up to 80 per cent accuracy, how long they'd stay. The project was developed on behalf of Boeing, so that the aircraft manufacturer could predict movements of workers in its factories.

Outside of industry, the technology might simply ensure that Wi-Fi access was available where and when it was most needed. But it could also form what's known as a 'pre-social network', which predicts where people who share your interests are likely to congregate – and when. It's eerily reminiscent of the film *Minority Report*, in which criminals are caught before they commit a crime.

It's the type of data mining that Pentland describes. "If I know where you go, I can do a good job of figuring out who your friends are and what you're going to buy," he says. However, as UCL computer scientist Peter J Bentley remarked about Jyotish on his blog: "I'm uncomfortable with the idea that my movements and social interactions could be predicted, and that prediction could be available to anyone."

It seems that in the social networking future, we're going to have to decide just how much data we're comfortable giving away. ■

"Social interactions could be predicted, and that prediction could be available to anyone"

***Christopher Mims is a contributing editor for* Technology Review**
Additional reporting by Graham Southorn

FIND OUT MORE

http://j.mp/InterLine
Hobbes' internet timeline

How Many Friends Does One Person Need?
by Robin Dunbar (Faber, 2010)

10 FACTS ABOUT SKIN

SUNCREAM WAS INVENTED BY SWISS CHEMIST FRANZ GREITER

After suffering sunburn while climbing Piz Buin mountain in 1938, Dr Greiter created 'Glacier Cream'. Later, in 1962, he introduced the Sun Protection Factor (SPF) – the worldwide standard for the effectiveness of suncream when spread at 2mg/cm^2 of skin. Glacier Cream had an SPF of 2, while today's suncreams can have SPFs of 30 or more. The higher the number, the longer you can avoid the burning effects of the Sun's UV-B radiation.

▲ YOUR SKIN IS THE BODY'S MAJOR BARRIER TO INFECTION

The outer layer of the skin, the epidermis, is your first defence against infection and disease. It consists mainly of keratinocytes – cells that contain the tough protein keratin that forms the basis of hair and nails. The epidermis is made up of several layers of keratinocyte cells (pictured), which are replenished as exterior cells flake off.

► SKIN COLOUR DEPENDS ON THE AMOUNT OF MELANIN PRESENT

A black-brown pigment, melanin is produced by skin cells and protects the skin by dissipating ultraviolet rays as heat energy. Dark black skin provides protection equivalent to SPF 13 and filters twice as much UV radiation as white skin. White skin only originated 20,000 to 50,000 years ago, due to a genetic mutation that occurred after humans migrated out of Africa to colder regions. The gene was discovered after the same mutation was shown to deprive zebra fish of their stripes.

27

days is the average time it takes an adult to shed and regrow the entire outer layer of the epidermis. By the age of 70, an average person will have lost 47.6kg of skin, or two-thirds of their body weight.

► SKIN HAS A DIVERSE ECOSYSTEM OF BACTERIA

According to the US National Institutes of Health, the most densely populated regions of our skin include behind the ear, the back of the neck, the sides of the nose and the belly button. Scientists think that skin bacteria play an important role in preventing disease: a study by the US Centers for Disease Control and Prevention found that 1.5 per cent of Americans had the superbug MRSA in their noses, but didn't show any infection. This suggests that it acts as 'good' bacteria keeping harmful germs at bay.

GETTY X2, SCIENCE PHOTO LIBRARY X2, THINKSTOCK X2, SUPERSTOCK

Summer is here, which means it's time to strip off and absorb some rays. On the 50th anniversary of the Sun Protection Factor, **Hannah Devlin** gets under your skin

◂ SOME SKIN CELLS DON'T NEED OXYGEN FROM BLOOD

Animals such as bullfrogs and leeches rely on their skin as their primary respiratory organ, absorbing oxygen and releasing carbon dioxide through the outer layer. While human skin hardly contributes to total respiration at all, recent research by scientists at the Max Planck Institute, Germany, shows that cells in the outermost 0.25-0.40mm of the skin (like this pore pictured), are almost exclusively supplied by external oxygen rather than oxygen carried in the blood.

2m^2 is the average area of an adult's skin and contains more than 18km of blood vessels. It's the biggest and heaviest organ in the human body, weighing 4kg – dwarfing the liver at around 1.5kg.

▾ TOUCH DETECTS FIVE DIFFERENT STIMULI

Skin has sensors dedicated to detecting pressure, heat, cold, pain and itchiness. Sensitivity to each of these sensations varies between different parts of the body, depending on the density of receptors. Pressure sensors called Meissner's corpuscles (artist's impression below) are most densely concentrated in the fingertips, palms, lips, tongue, nipples, penis and clitoris, and least dense on the back, torso and calves. The number of Meissner's corpuscles per square millimetre of skin on the fingertips drops fourfold between the ages of 12 and 50, meaning that we lose our sense of touch with age.

8 litres is the volume of sweat the skin can release through its sweat glands in one day, although the average volume varies widely. When exercising at the same relative intensity, men start perspiring more quickly than women and twice as profusely.

▴ FINGERPRINTS HAVE BEEN USED AS IDENTIFIERS FOR 4,000 YEARS

The first documented use was in ancient Babylon, for legal contracts to protect against forgery. As well as helping apprehend criminals (the first British fingerprint bureau was set up by Scotland Yard in 1901), the grooves of fingerprints help us perceive fine textures and improve our grip. Similar prints are found on the underside of the tails of New World monkeys, which helps them grasp branches.

BBC TWO Look out for a Horizon programme on skin in late July

Q&A

Your questions answered

Can you hypnotise a baby to sleep? p75
How do binary stars form? p77
How many cold and flu viruses are there? p78
Why can't we see the wind? p81

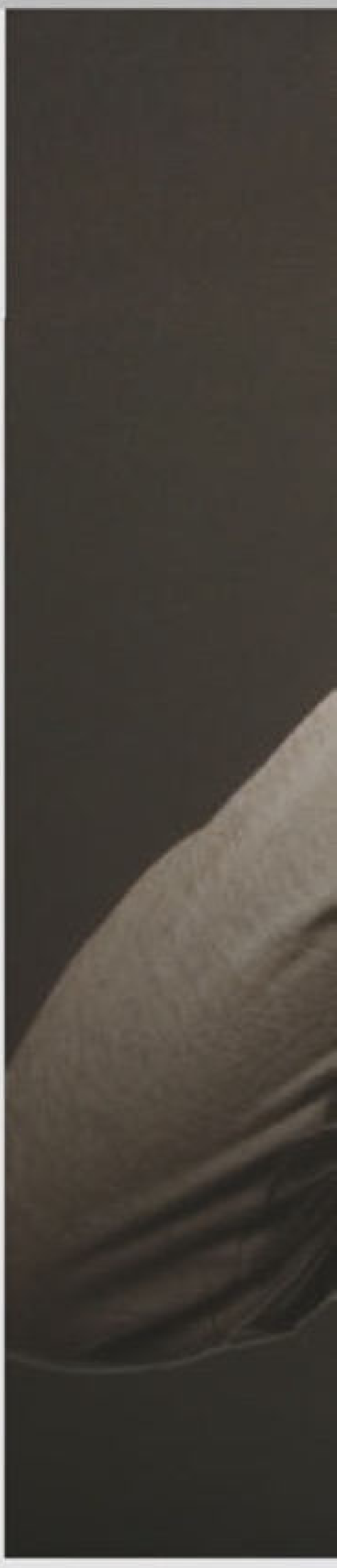
On a desert island, would it be better to drink wine or go thirsty?

MIRANDA CADDY, LONDON

The amount of water you lose through urinating is controlled by the Anti Diuretic Hormone (ADH, also called vasopressin). ADH causes your kidneys to extract excess water from your urine so that it can be recycled back into your body. Without any ADH at all, your kidneys would dump about 10 litres of water a day into your bladder; ADH reduces this to one or two litres.

Alcohol increases the amount you urinate because it suppresses the production of ADH. A sufficiently alcoholic drink can suppress ADH to the point where your kidneys actually excrete more water than the volume of the drink itself, and so there's a net dehydrating effect. But the concentration of alcohol required for this increases as you get thirstier. If you just drank wine on your desert island, you would initially lose more water than you gain from the wine, but as your body became more dehydrated, it would produce more ADH to compensate and you'd eventually reach an equilibrium point.

For the 13 per cent alcohol content of most wines, that equilibrium point would still leave you badly dehydrated (not to mention hopelessly drunk), but it should prevent you dying of thirst. If a six-pack of beer (5 per cent alcohol) washed up next to the wine, that would be a better choice. **LV**



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35,000

genes make up a Heinz 1706 tomato. The tomato's genome was recently fully sequenced after nine years of research

Send us your questions

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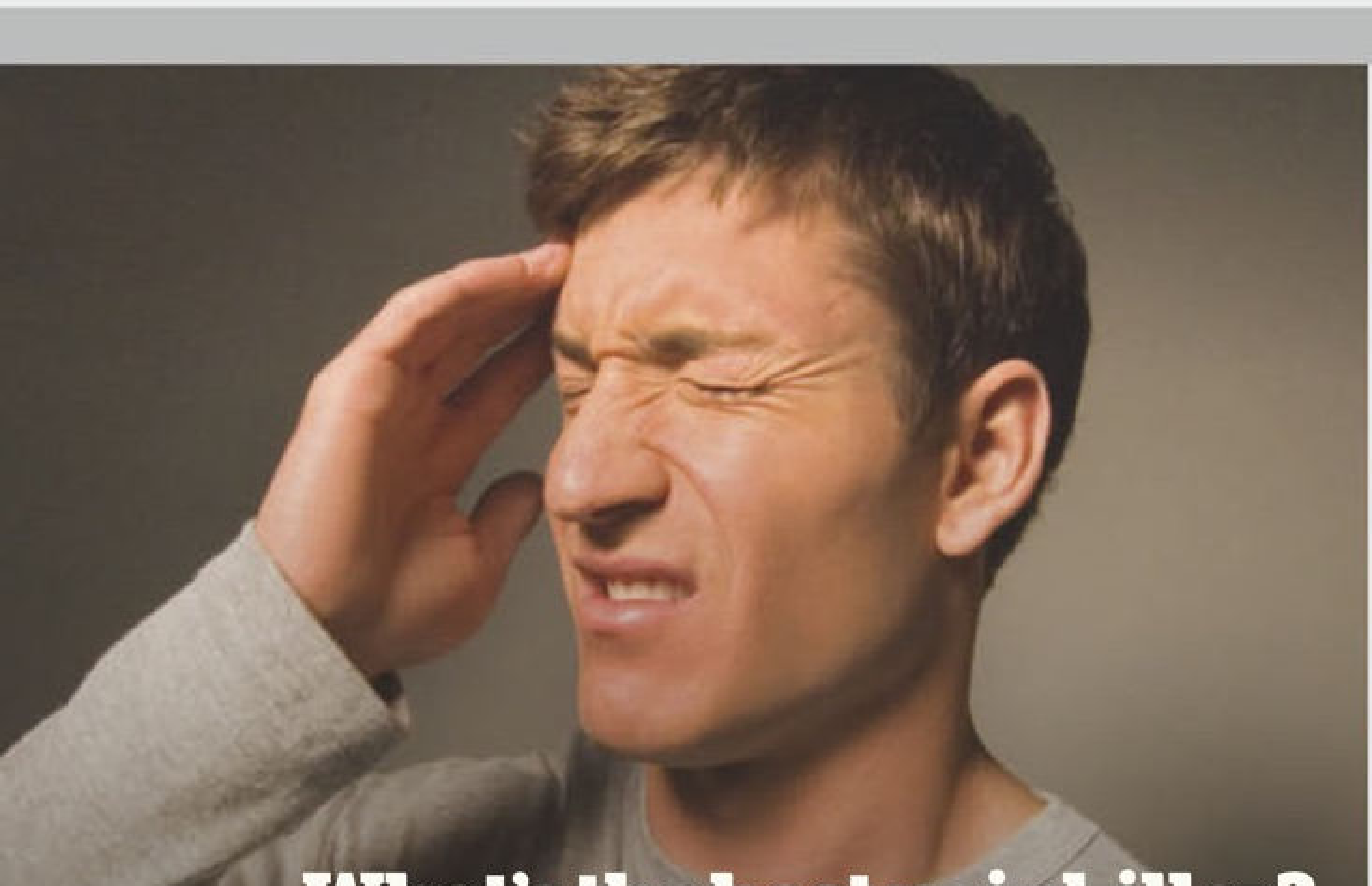


What's the best painkiller?

SAM FOLEY, BASINGSTOKE

When experiencing a bad headache or other acute pain, most people reach for tablets of the 'big three' over-the-counter painkillers: aspirin, paracetamol or ibuprofen. But which one works best? A recent study by a team led by Dr Andrew Moore of the Pain Research Unit at the Churchill Hospital, Oxford found that aspirin only works well in around 35-40 per cent of people, compared to 45 per cent of those taking paracetamol and 55 per cent for ibuprofen. The proportions for all these increase by around 5 to 10 percentage points if 100mg of caffeine are added. According to Dr Moore, the best results come from a combination of 500mg of paracetamol, 200mg of ibuprofen plus a strong cup of coffee. He cautions, however, that anyone with recurrent pain should see their GP. **RM**

How big was the Universe at the point of the Big Bang?

PHIL COATES, LANCASHIRE

The Universe was created during the Big Bang at a single point known as a 'singularity'. The singularity wasn't a point within our Universe – it was the Universe. That singularity marked the creation of space and time and from it came all the matter and energy of the Universe. At the moment of the Big Bang this singularity had infinite density, was infinitely hot and had zero size. But a 'zero-sized' Universe is a problem for physics. It appears that lengths smaller than about a quadrillionth the size of an electron actually have no physical meaning. At these minute scales, our physical theories break down completely and so science can say nothing about that very first moment. But the Universe didn't stay 'zero-sized' for long. In about a millionth of a second it had grown to about the size of our Solar System, and it's been expanding ever since. **AG**

Can other animals be right- or left-handed?

DAVE HARRIS, BATH

Yes – or right-eyed or left-footed. In the 1930s parrots were given slices of carrot or apple, which they picked up with one foot before eating. Seventy-five per cent used their left foot, and in some species every bird was found to be left-footed. Fish tend to dodge consistently either left or right when evading a predator, using their preferred eye to deal with the threat. Humpback whales prefer the right side of their jaws when feeding. Cats and dogs have preferences, too. In one study, psychologists in Belfast played for weeks with 42 pet cats. Although the cats would use either paw for easy tasks they reverted to their favoured side for more complex ones. In females this was usually the right paw, and in toms the left. In the tricky task of fishing a piece of tuna out of a small jar, all 21 females used their right paw. Dogs behave similarly until they are spayed or neutered, when the difference disappears, suggesting hormones play a role in left- or right-handedness. SB

The **experts**

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach the Ground*

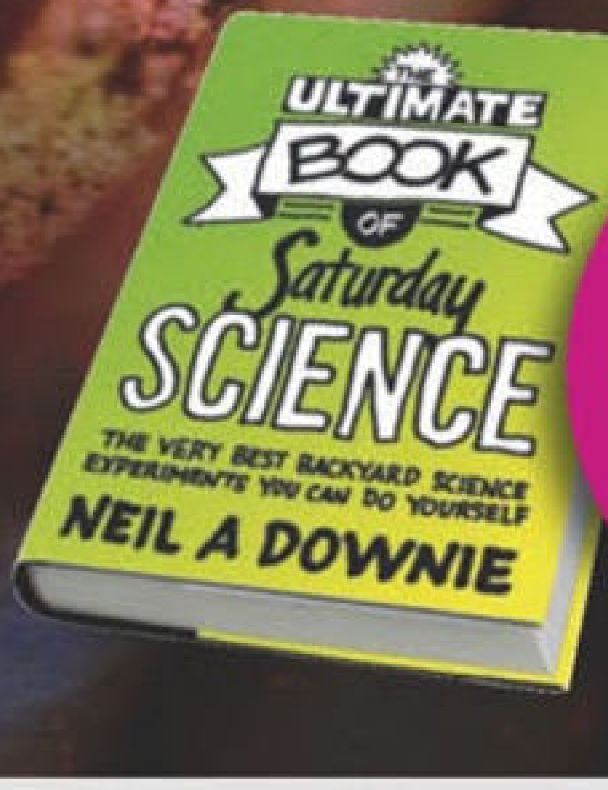
QUESTION OF THE MONTH

Why does light travel in waves through a vacuum?

MARTIN WALTERS, BRISTOL

The laws of physics view light either as a stream of particle-like packets of energy called photons, or as electromagnetic waves. While the idea of photons travelling through a vacuum is easy to visualise, the concept of waves seems to demand an all-pervasive 'fluid' through which the waves can pass. It's often said that the existence of such a fluid – known as the aether – was disproved by Einstein's theory of relativity, but that's not true.

Einstein proved only that the aether must be utterly featureless, to prevent anyone detecting motion relative to it. It's now known that quantum theory actually *demands* the existence of an aether-like fluid through which light waves pass. Known as the quantum vacuum, its existence was demonstrated in the 1940s – thus proving that 'empty' space isn't actually empty at all. **RM**

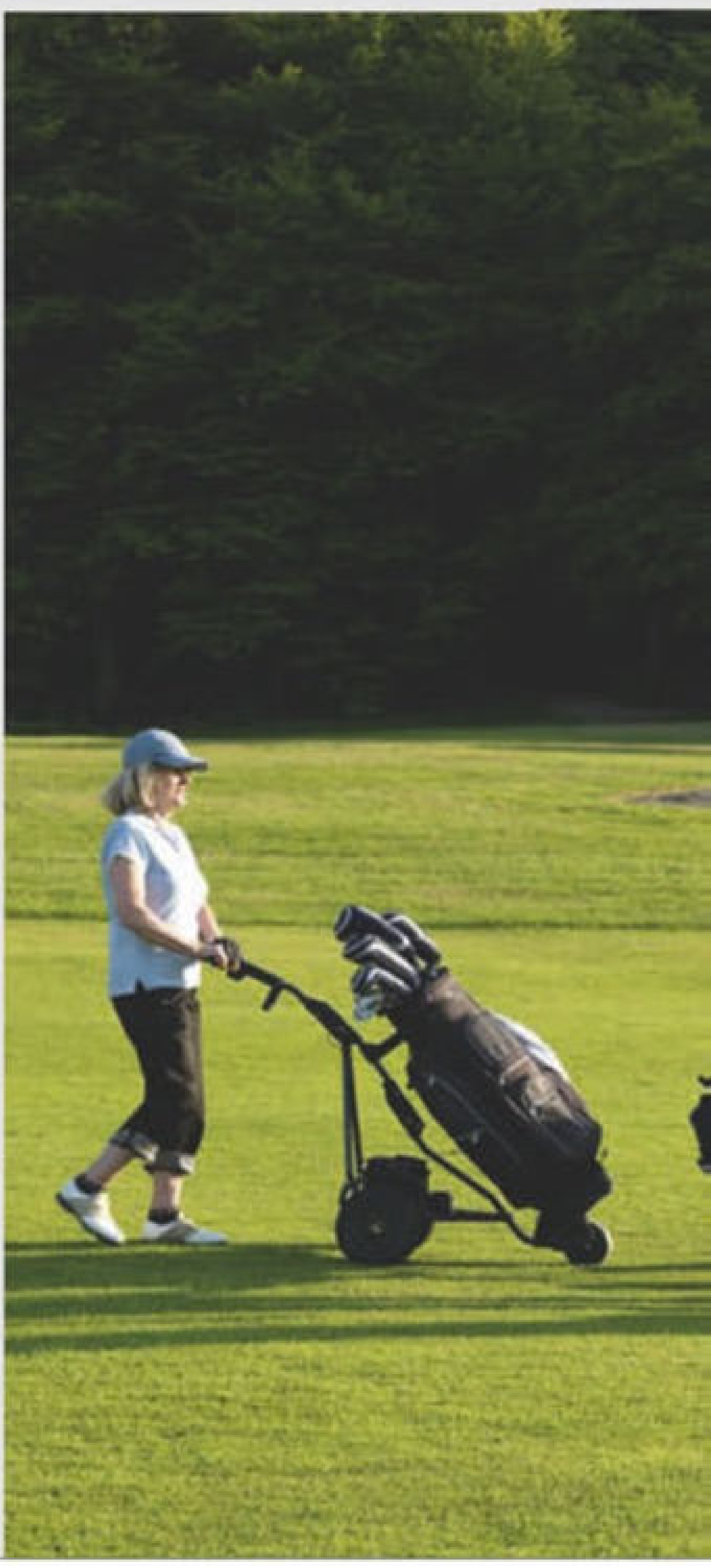

THE ULTIMATE BOOK OF Saturday SCIENCE
THE VERY BEST BACKYARD SCIENCE EXPERIMENTS YOU CAN DO YOURSELF
NEIL A DOWNIE

Martin wins a copy of The Ultimate Book Of Saturday Science by Neil A Downie (Princeton, £16.44)

Why do sheep and cows taste different when they both eat grass?

MATT ELLIS, BASINGSTOKE

For much the same reason that they look different: cows and sheep are different species with different DNA. Although the basic structure of muscle tissue is the same in all mammals, much of the flavour of meat comes from the specific fats that the animal uses as an energy store. These are different from one species to another, and depend on the diets that these animals originally evolved to eat. Wild sheep browse leaves and herbs as well as just eating grass, and so domesticated sheep are given feed supplements that are different from those fed to cows. The gut bacteria of sheep comprise a different mix of species as well. The result of all this is that sheep produce more 'branched chain' fatty acids, with eight to 10 more carbon atoms per molecule than cows. It's these that give lamb its distinctive taste. **LV**



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Can you hypnotise a baby to sleep?

MICHAEL WALSH, NORTHERN IRELAND

There is still no clear scientific consensus on whether hypnosis constitutes a separate state of consciousness, or merely a sort of socially conditioned, imaginative role-play. MRI scans and EEG measurements have failed to find anything that corresponds to a hypnotic trance, for example. The non-state interpretation of hypnosis assumes that the person being hypnotised understands both what is being said to them, and what is expected of them as subjects of hypnosis. That seems doubtful in the case of babies.

What's more, the techniques that might be used to 'hypnotise' babies – focusing your attention fully on them, speaking in a low, steady voice, gently rocking and so on – are much the same as the ones you would use to just send a baby to sleep naturally. And if your baby falls asleep, then by definition it isn't hypnotised. **LV**

Is it more efficient to push or pull a golf trolley?

RICHARD O'NEILL, GLASGOW

As long ago as 1973, research at the University of Texas found that the human skeleton exerts the most pushing force when your hands are at 70 per cent of your shoulder height from the floor, which is roughly chest height. When you are pulling, however, this changes to 40 per cent of shoulder height, or between the hip and knee. Three- and four-wheel trolleys stay upright and the handle is too high for efficient pulling, so you should push them. But the traditional, two-wheeled golf trolley tilts up when you roll it so the height of the handle is much closer to the ideal pulling height. Pulling a trolley also saves some energy in steering, because the wheels are behind the towing point, so it automatically follows you. When you push a trolley, you'll need to exert some extra force at the wrist as you continually adjust its course. **LV**

QUICKFIRE

Is graphene biodegradable?

AMY RHYS-DAVIES, CAMBRIDGE

Graphene is a form of carbon where the atoms are arranged in a hexagonal grid, like chicken wire, to form a single giant molecule with each carbon atom anchored to three others by covalent bonds. That makes it very stable. Like other pure forms of carbon (diamond, carbon nanotubes, etc) it isn't biodegradable and doesn't react with most solvents or acids. **LV**

Why does it take litter so long to degrade?

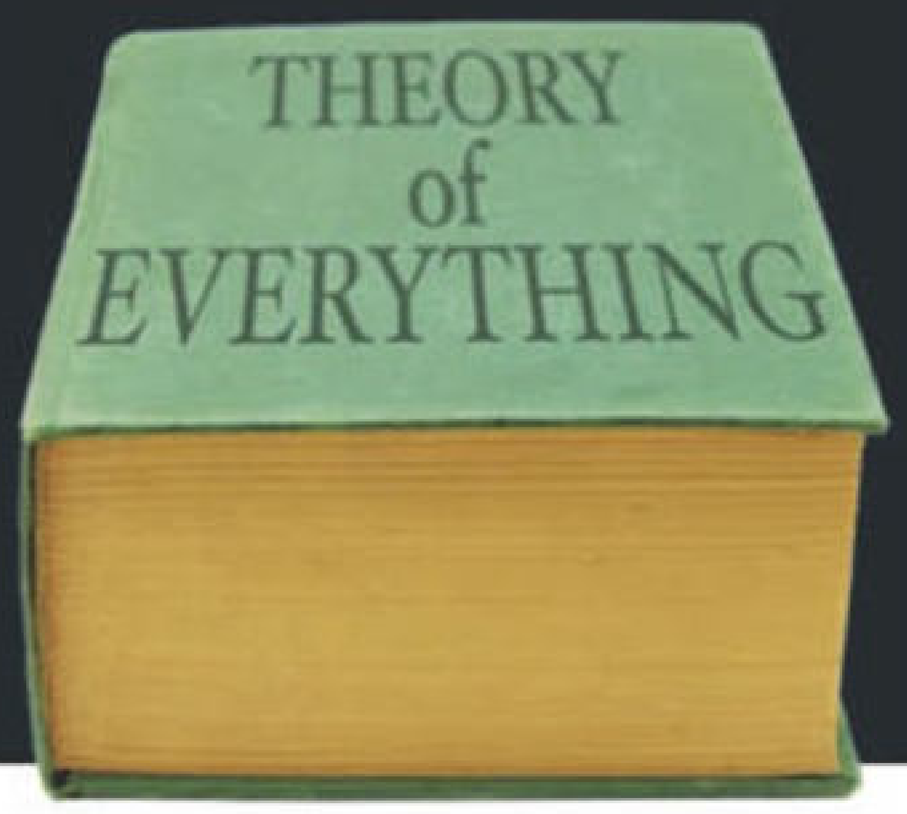
GEORGE CLARK, NOTTINGHAM

It depends on what the litter is, and where it is. Organic litter such as paper left exposed to the elements will disintegrate under the action of sunlight, rain and bacteria within a matter of weeks. Tin cans buried in a tip will last for around a century before rust destroys them, while glass is so chemically unreactive that bottles can last for millennia. **RM**

Why do we need a Theory of Everything?

GEORGE COLLINS, HEREFORD

The prime motivation of the quest for the Theory of Everything is to confirm the age-old belief in the underlying unity of Nature. For physicists, this means showing that all the forces in the Universe and the particles on which they act are manifestations of one unique phenomenon. At present, the best candidate for that phenomenon is the vibration of incredibly tiny, multidimensional entities known as superstrings. To date, however, evidence for their existence remains tentative. **RM**



TOP TEN CLOSEST STARS TO EARTH

(Distance from Earth in light-years)

Sun
0.0000158
Our parent star's light takes just over eight minutes to reach us

Proxima Centauri
4.242
A red dwarf star not visible to the naked eye

Alpha Centauri
4.365
The third brightest star in the night sky

Barnard's Star
5.963
One of the oldest stars known

Wolf 359
7.782
One of the faintest and lowest-mass stars known

Lalande 21185
8.290
A dim red dwarf star that emits mostly infrared radiation

Sirius (the Dog Star)
8.582
The brightest star in the night sky

Luyten 726-8
8.728
The first flare star to be discovered

Ross 154
9.681
The nearest star in the constellation of Sagittarius

Ross 248
10.322
May be closer than Proxima Centauri in 33,000 years' time

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Why do humans cry?

LUKE AZZOPARDI, MALTA

Either for emotional reasons, or to wash away irritants such as dust, grit, insects and 'lachrymatory agents' – chemicals that make you cry. When an onion is cut, its enzymes mix with sulphoxides and sulphenic acids to produce a gas called propanethiol S-oxide, which reacts with tears to form sulphuric acid. This irritation alerts brain systems that then tell the lacrimal glands to stimulate tears to wash it away. These are called 'reflex tears' and are also provoked by coughing and yawning.

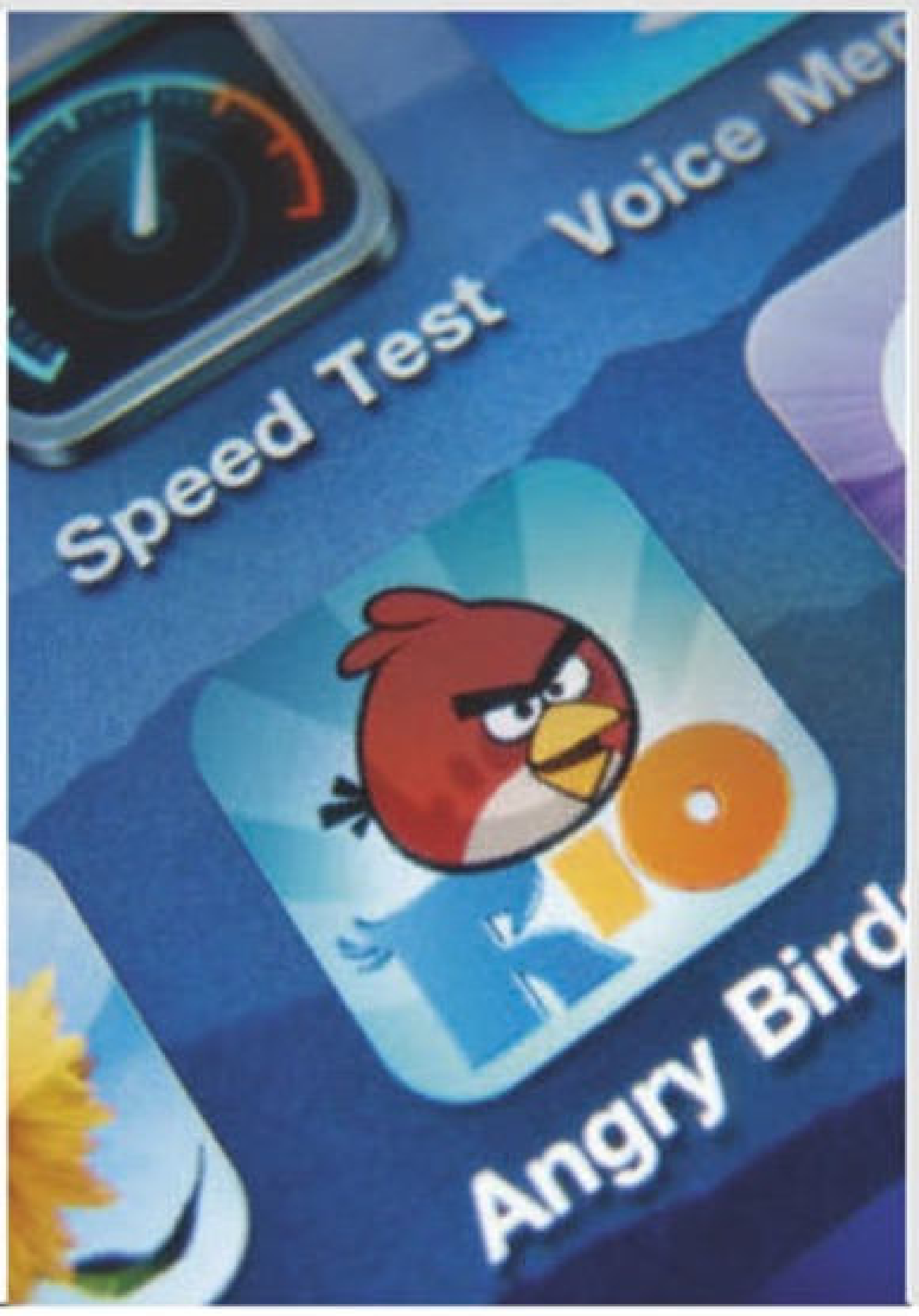
Emotional tears are different, containing more prolactin, adrenocorticotropic hormone and encephalin (a natural painkiller). Parts of the brain's limbic system, including the hypothalamus, control emotional responses including fear, anger and grief, and can signal the lacrimal glands to produce tears.

The really difficult question is why emotional humans cry at all. The reason may be social. Blurred vision and sobbing provide a social signal of weakness and neediness, and crying can bring groups together – for example, when a family is in a state of grief. **SB**

What is the highest-grossing iPad or iPhone app?

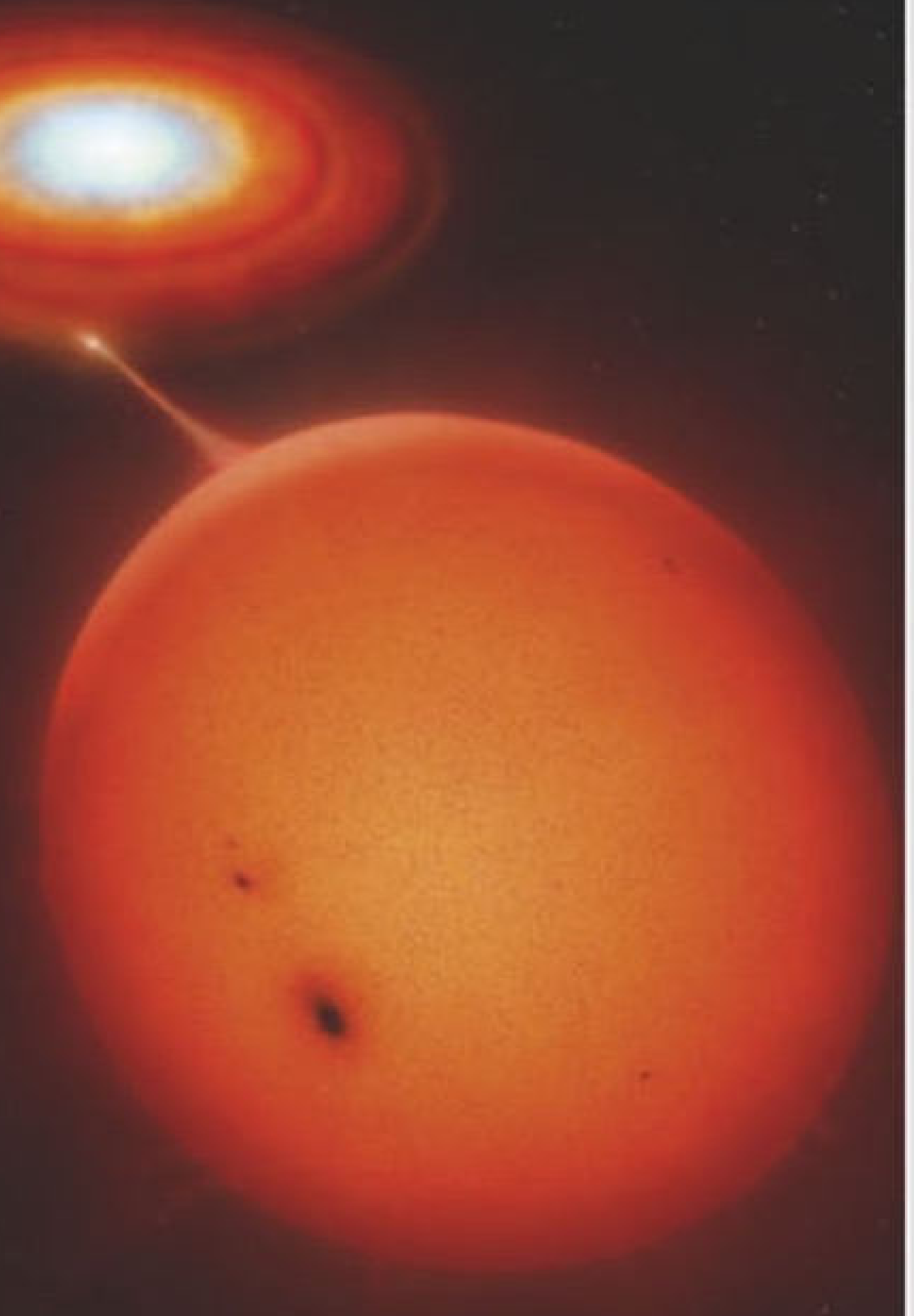
MATT HOSKINS, HARROW

At the time of writing, the highest-grossing iPad app via the UK iTunes store is Quickoffice Pro HD. On the iPhone, the gong goes to Draw Something. When Apple celebrated the 25 billionth app download in March, Angry Birds was the all-time most popular, and sequel Angry Birds Space grossed $9.9 million in its first 10 days. There is no openly available data for the single highest-grossing app ever, but in January, Apple announced it had paid $4 billion to developers in total. As the company takes about 30 per cent commission, the sum total of all app revenue since the iTunes app store launched in 2008 is around $5.7 billion. **GM**



How do binary stars form?

CLAUDIA MASSEY, SHEFFIELD



Binary stars, and in fact multiple star systems, are surprisingly common. Perhaps half of all bright stars are multiple, and possibly a quarter of all faint stars. Stars form when large clouds of dust and gas collapse under their own gravity. Eventually such clouds form into disc-like structures. If the dense central regions of these proto-stellar discs reach a critical limit, internal nuclear reactions begin and a star is born.

Binary or multiple star systems form when turbulence or density variations fragment the proto-stellar disc and the resulting clouds condense in close proximity. It is also possible that some extremely close binary stars form when a young star's leftover disc collapses itself. In very densely populated 'globular clusters', some binary stars may form when one star gravitationally captures another. **AG**

Why do we get tired?

JOANNA TAYLOR, CHESHIRE

Tiredness, like hunger, is a warning signal to encourage us to rest. Sleepiness is governed by the levels of the hormones adenosine and melatonin, which gradually accumulate during the day. The function of sleep isn't well understood but it seems to be important for tissue repair and growth, as well as memory processing. It isn't simply a question of conserving energy. Hibernating squirrels will periodically raise their body temperature to enable them to transition from hibernation to ordinary sleep. This shows that sleep is an active process that is worth spending energy on, even in a completely resting animal. **LV**

Why aren't we genetically identical to our siblings?

MATT DIXON, BRIGHTON

In sexually reproducing species, eggs and sperm are created in a process called meiosis. Most human cells contain 23 pairs of chromosomes. In meiosis, the two chromosomes in a pair are split apart, making an egg or sperm which has just single chromosomes. When an egg and sperm fuse, the chromosomes from each come together to make new pairs. In a process called 'crossing over', their genes are shuffled so that the resulting new cell is a completely unique mixture of the genes inherited from each parent.

That's the mechanism, but the deeper question here is why, in evolutionary terms, it is worth so many plants and animals going through this extraordinarily complex process at all. The two main theories are first, that it helps with DNA repair and avoids errors; and second, that it increases genetic diversity, which is essential if creatures are to be able to adapt in changing environments. **SB**

What actually happens when your leg 'goes to sleep'?

CLAIRE SMITH, ST ALBANS

The temporary numbness is called paraesthesia and is caused by pressure on the *vasa nervorum*, the small arteries that supply oxygen and nutrients to the peripheral nerves of the body. When these arteries are squeezed, the nerves become partially starved of oxygen. Blood pressure behind the blockage also rises and this causes fluid to leak from the blood vessels and squeeze the nerves themselves. As the nerves stop firing, sensory signals from the skin don't reach the brain, so your leg feels numb, and motor impulse signals are unable to reach the muscles, so your leg becomes floppy and unresponsive.

Once the pressure is removed, blood starts to flow again but different nerves recover at different rates. So you feel the hot flush as the temperature-sensitive nerves reactivate, before your motor nerves allow you to move the foot. Finally, the sensory nerves in the skin begin firing wildly, which gives the pins-and-needles sensation. **LV**

How many cold and flu viruses are there?

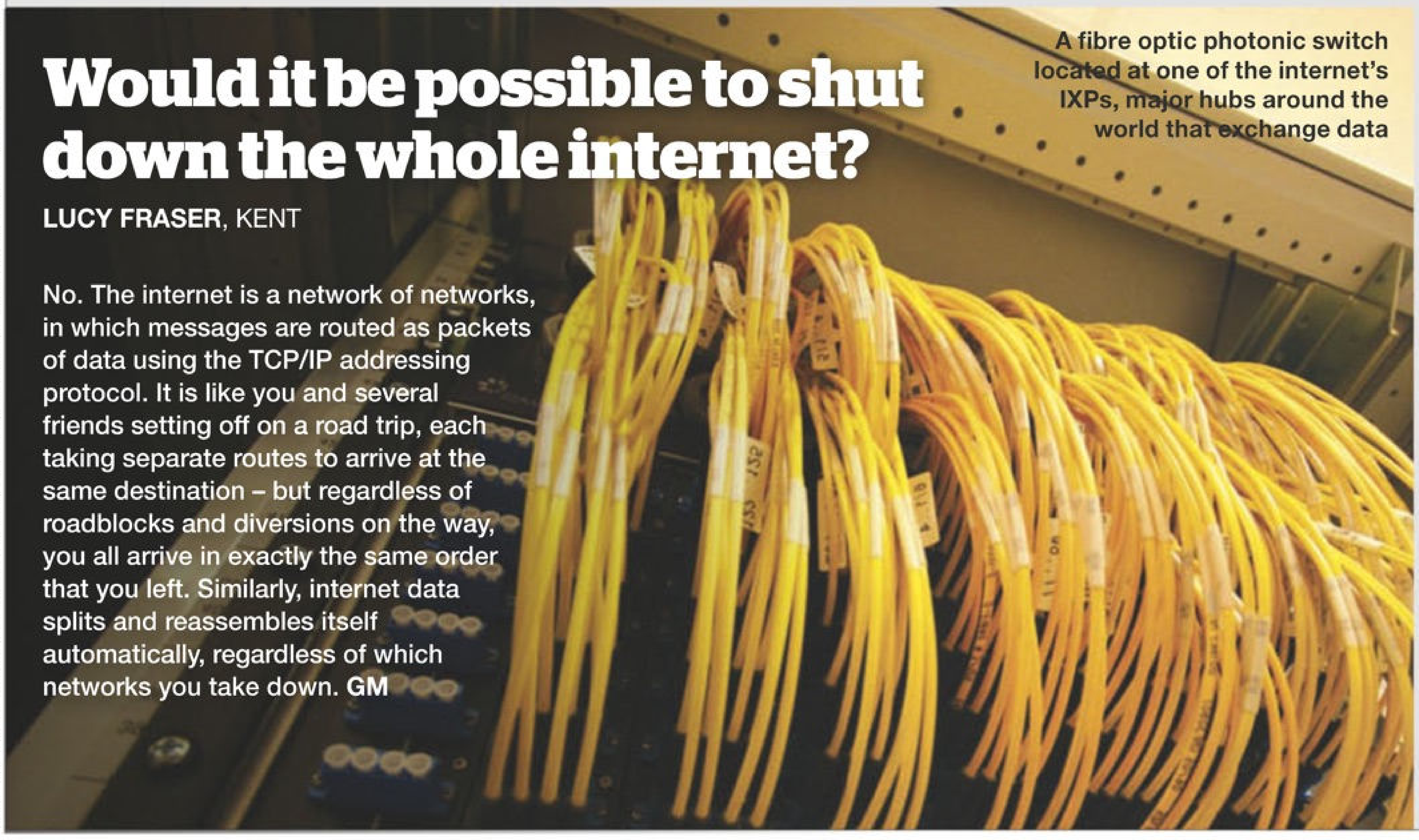
PAUL LESLIE, BY EMAIL

There are about eight species of cold virus and another three for influenza. But the definition of species isn't entirely precise when dealing with viruses. When considering treatment and vaccination, it's more useful to talk about serotypes, which are variations in the surface proteins from one virus to another. There are over 200 different serotypes that cause colds and 18 for flu, with new ones mutating all the time. **LV**

Is a melted magnet still magnetic?

DAVE LEONARDSON, BRISTOL

No. A magnet consists of millions of tiny regions around 0.01mm across known as domains, whose spinning electrons are aligned with each other. Such an orderly state breaks down when heat is applied, and disappears completely above the so-called Curie Temperature (named after the husband of the famous chemist Marie Curie). For iron this is around 770°C, well below its melting point of 1,530°C. **RM**



A fibre optic photonic switch located at one of the internet's IXPs, major hubs around the world that exchange data

Would it be possible to shut down the whole internet?

LUCY FRASER, KENT

No. The internet is a network of networks, in which messages are routed as packets of data using the TCP/IP addressing protocol. It is like you and several friends setting off on a road trip, each taking separate routes to arrive at the same destination – but regardless of roadblocks and diversions on the way, you all arrive in exactly the same order that you left. Similarly, internet data splits and reassembles itself automatically, regardless of which networks you take down. **GM**

DID YOU KNOW?

In March 2010, a modified Volkswagen Scirocco was driven the 337km (209 miles) from London to Manchester – the longest journey ever undertaken in a car powered by coffee. The coffee granules were heated to release hydrogen, which was then combusted to drive the engine.

GETTY, DREAMSTIME, THINKSTOCK X5, ALAMY, FABIENNE SERRIERE, RICHARDPALMERGRAPHICS.COM

What would happen if you set off a firework on the Moon?

TOM BROOKS, PLYMOUTH

Nothing. Since there is no oxygen in the Moon's almost non-existent atmosphere, there is nothing with which the inflammable materials in fireworks can ignite. However, if there were oxygen present, a firework could travel six times as high as on Earth. This would mean the most powerful mortar-launched fireworks could easily reach over a mile above the Moon's surface. **AG**

What is the maximum data-carrying capacity of fibre optic cables?

SCOTT LLOYD, LEIGH

Deutsche Telekom in Germany reckons it holds the record at 512Gbps along a single fibre 1,500km in length. That is enough capacity for over 25,000 homes with 20Mbps connections. The Deutsche Telekom result uses just one wavelength of light. But there is a way that much more data could be carried: multiplexing allows multiple data channels to be carried across a range of wavelengths – it's a bit like tuning into stations on your radio, where different channels each have their own frequency. Likewise, a fibre carries a range of frequencies, each carrying its own channel of data. Japanese trials have employed wavelength division multiplexing to achieve 14Tbps along a single fibre. **GM**

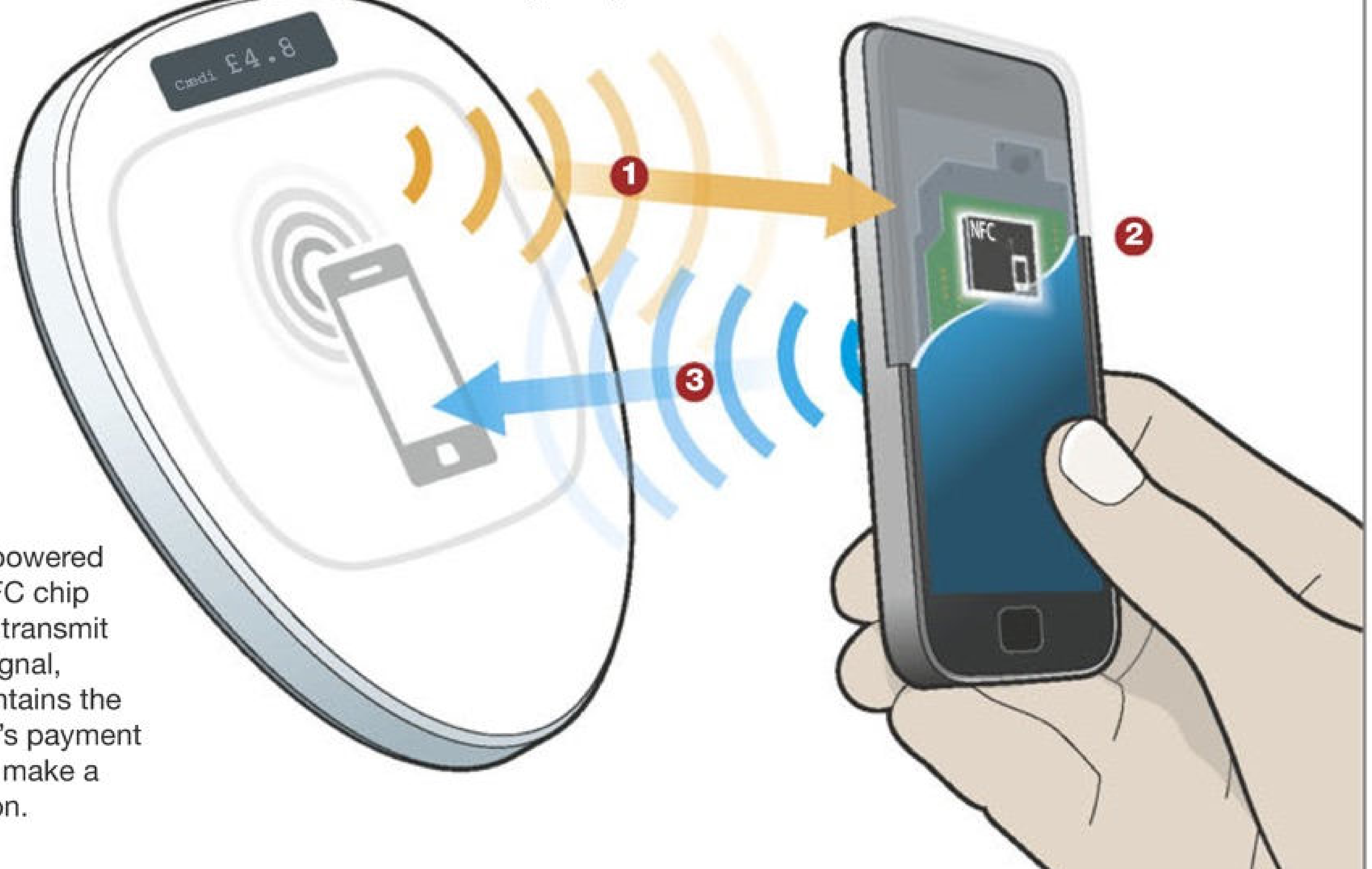
How will NFC technology replace cash?

Near Field Communication (NFC) technology enables short-range radio communication between devices and is becoming increasingly commonplace. Indeed, you may already have the hardware sitting in your pocket: by 2014 one in five smartphones will pack an NFC chip. The tech is an updated version of RFID, which you may have used on the London Underground in the form of an Oyster card that you tap on a turnstile to pay for your journey.

NFC only operates over very short distances, typically around 4cm, making it ideal for tapping a device with another – to make a secure payment, for instance. There is always an initiator chip and a target chip. The target receives power via a process called magnetic inductive coupling (as used to charge your electric toothbrush) when it comes within range of the initiator's low-frequency radio wave field. A magnetic field induces a charge in the target chip's circuitry, and once it's powered up it can exchange data with the initiator. This means that the target chip doesn't require its own power source and can therefore be made very small, making it perfect for incorporating into items such as mobile phones, stickers and key fobs.

The fact that NFC only operates over a very short range gives it an advantage over other wireless technologies like Wi-Fi and Bluetooth, where sensitive data such as a PIN number can be intercepted. The industry standard transmission frequency for data across NFC is 13.56MHz. This enables it to transmit a rather paltry 106 to 424kbps, although this is more than adequate for simple instructions. Compare this to the 3G phone signal, which operates at around 2Mbps, at which speed it can provide full use of the internet on the move.

NFC has a wide range of applications, the full potential of which is only just being realised. For instance, Barclaycard is turning this year's Wireless Festival completely cashless, with music fans able to simply load up an NFC wristband with beer tokens. In the future, doctors might be able to scan a patient's phone with an NFC-enabled device to get live health data, such as blood pressure and temperature, that's been gathered by the phone using sensors.



1. A powered NFC chip in a pay-station emits a short-range radio signal.

2. The radio signal induces a charge in a mobile's NFC chip when it comes within range – typically 4cm.

3. Once powered up the NFC chip is able to transmit its own signal, which contains the customer's payment details to make a transaction.

Where do 'lost' eyelashes in eyes go?

AMI JAY, HIGH WYCOMBE

They get washed out by your tears. The conjunctiva is attached to the inner edge of the eyelids so it's impossible for anything to get trapped behind the eye. Sometimes a loose eyelash will slightly scratch the inside of the eyelid when you blink. This makes it feel as if the lash is still there, and you keep looking for it after it has gone. **LV**

Why do we gasp when we are scared?

SOPHIE FOOTITT, BY EMAIL

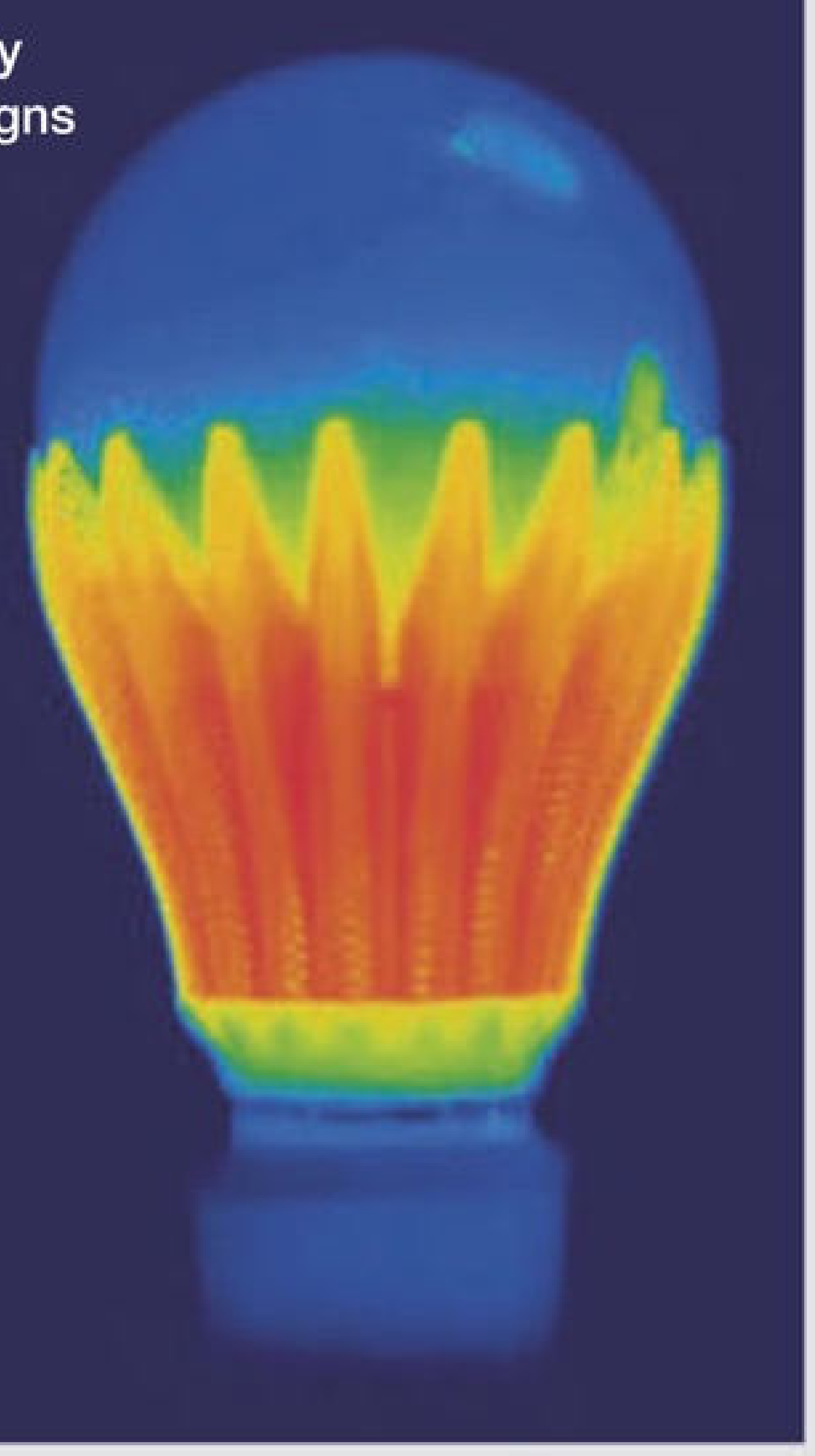
Probably to grab a little extra oxygen. Gasping is part of the flight/fight response in which adrenalin and other hormones are released to prepare the body for action. These dilate pupils, speed up heart rate, breathing and metabolic rate, and supply more fuel to the muscles. All these changes mean using oxygen more quickly, so a good deep gasp might be a useful precaution. **SB**

Is there a limit to the size of an LED light bulb?

DAVID PUGH, NEWMARKET

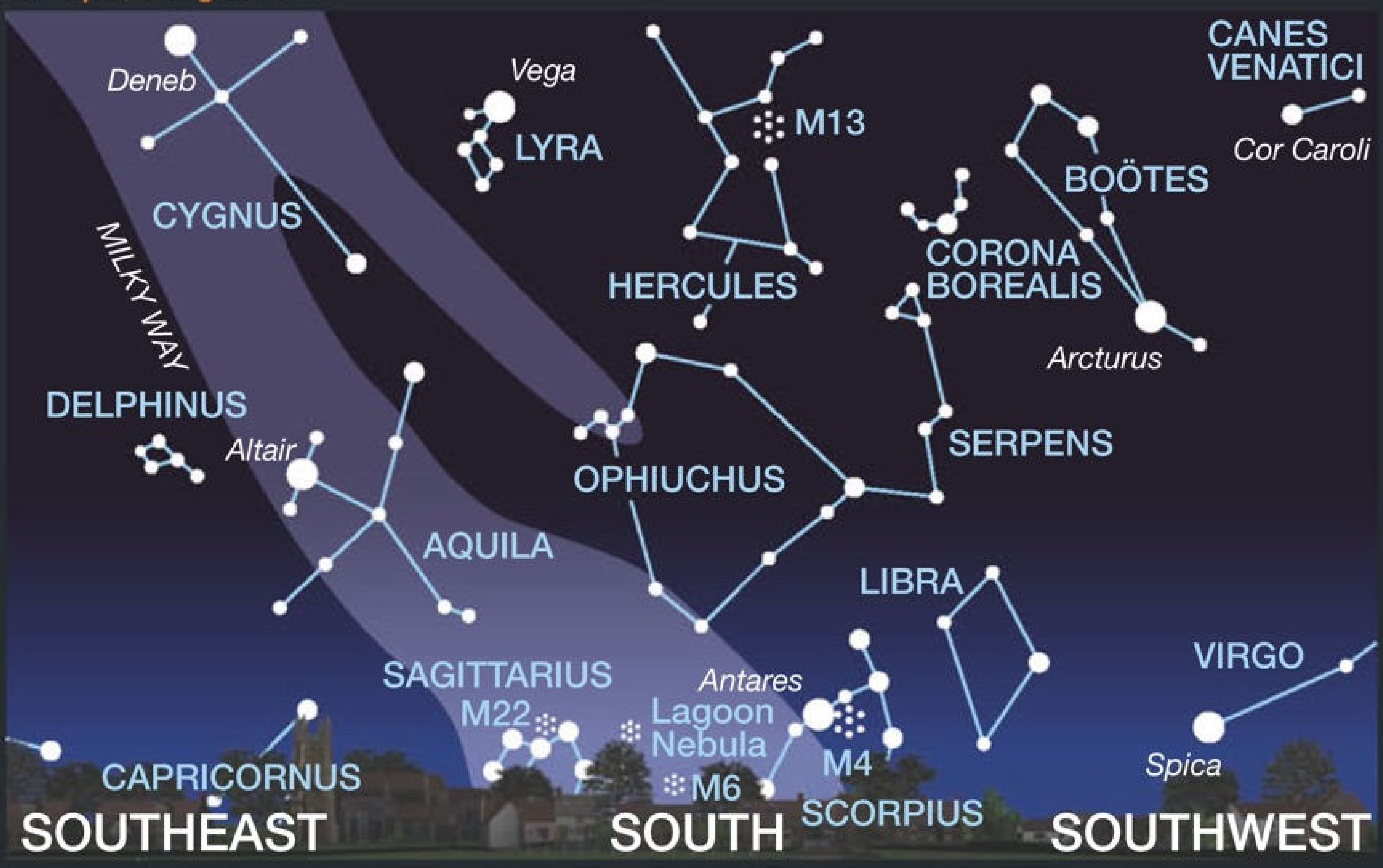
Like most semiconductors, LEDs are built on silicon chips. Each device on the chip must dissipate heat to avoid cooking itself. The higher the power, the more heat needs to be soaked away into the chip. This limits the size of each individual LED.

To improve energy efficiency, new designs use microscopic structures called photonic lattices. These guide light away from the diode, reducing the amount reflected back into the device, thus maximising brightness. **GM**



Skywatching with astronomy gurus Heather Couper and Nigel Henbest

10.30pm, 1 August 2012



Aim a pair of binoculars up at Hercules to pick out M13, the Great Globular Cluster. Its tight-knit group of 300,000 stars will look like a hazy patch. If you have a telescope you'll be able to make out individual stars

What can I see this summer?

- **Overhead, evenings**
The constellation of Hercules strides across the summer skies. For a Roman god, its stars are unfairly dim. But look to the right of Hercules to spot M13. This globular cluster is one of the oldest objects in the Galaxy.

- **Southwest, evenings**
Scorpius is a sensational constellation. From the UK we can't see it in all its majesty, but we can admire its brightest star, Antares. This red giant is 10,000 times more luminous than the Sun, and 700 times bigger.

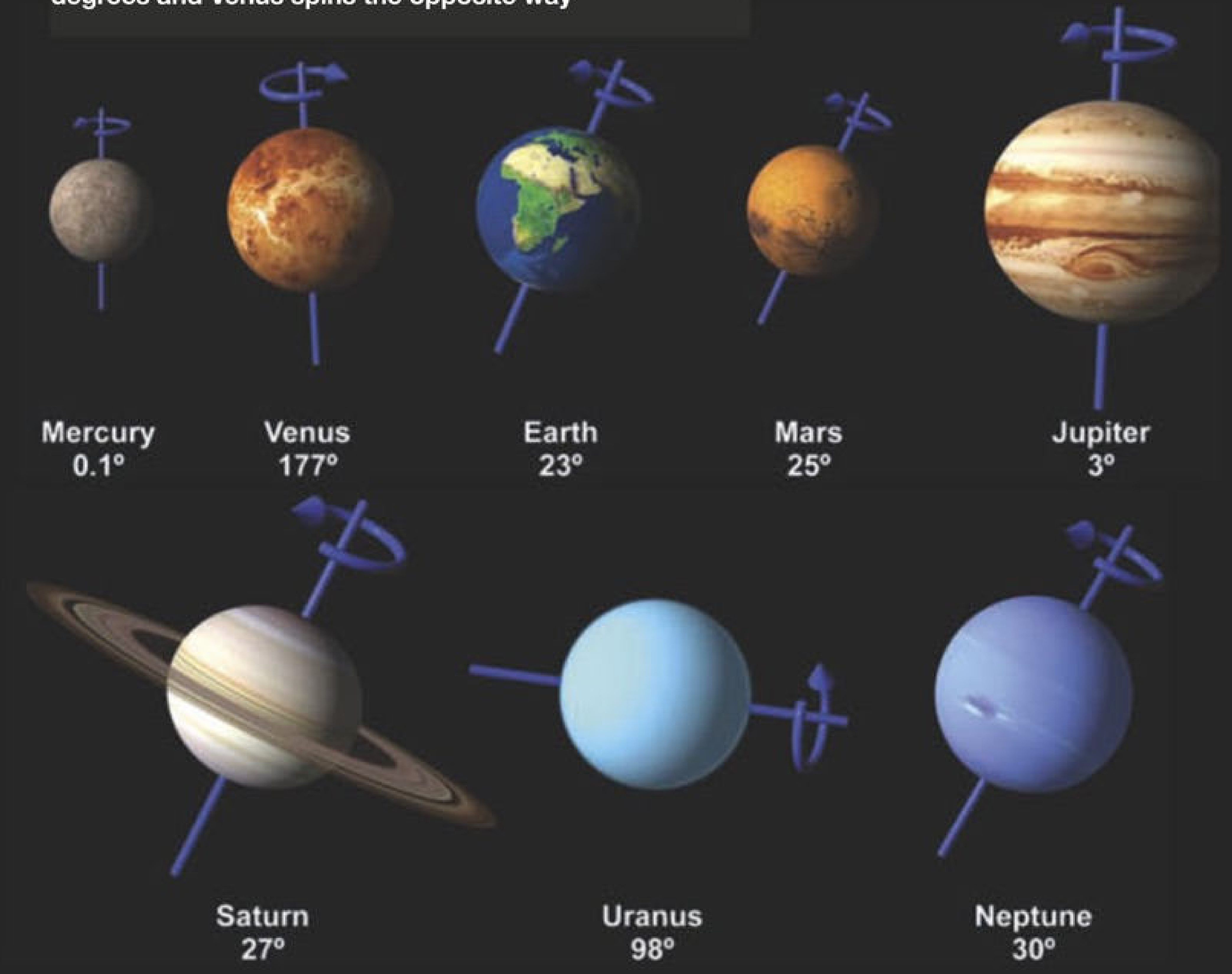
- **South, evenings**
Look towards Sagittarius and your eyes are aimed at the centre of the Milky Way – and along its spiral arms, nebulae and star clusters pile up. Look for the glorious Lagoon Nebula, then sweep the rest of the constellation for a cornucopia of fuzzy celestial delights.

Watch *The Sky At Night* on BBC One. Check radiotimes.com for details

BBC one

THINKSTOCK X2, SUPERSTOCK X2, CALVIN J HAMILTON, ILLUSTRATION BY PAUL WOOTTON

The planets' axes of rotation are tilted by various degrees and Venus spins the opposite way



Do all planets spin the same way?

JENNIFER DENNIS, GLASGOW

Most planets (including Earth) rotate anti-clockwise when viewed from above their north poles. This reflects the original rotation of the proto-stellar disc that formed the Sun and planets. However, Venus rotates clockwise when viewed above its north pole while Uranus's rotation axis is tilted almost perpendicular to its orbital plane. The most common theory as to why the rotations of Venus and Uranus are different from those of the other planets is that they were involved in violent collisions soon after their formation. **AG**

Why can't we see the wind?

BRIAN ATKINSON, BROMLEY

Air is transparent to our eyes because we have evolved retinas that are sensitive to the very wavelengths of light that pass through it unobstructed – otherwise we wouldn't be able to see anything at all. Wind is just moving air, caused by pressure differences in the atmosphere. Low-pressure air is slightly less dense than high-pressure air and so has a lower refractive index, which affects the path of light rays slightly: stars 'twinkle' in the sky because of the tiny distortions in the atmosphere, but you can't observe the effect with ground level objects, because they are much nearer and your brain processes signals from your eyes to present as stable an image as possible.

But you can see wind in indirect ways, from the movement of hair, trees and clouds. The funnel of a tornado is visible because the pressure drop in the centre causes water vapour to precipitate. **LV**

Why do we grow two sets of teeth?

TREVOR NEWMAN, SOLIHULL

Probably because we grow so much. Our milk teeth or deciduous teeth, appearing between eight months and three years old, are much too small and weak to last into adulthood. At about age six they are pushed out by much tougher permanent teeth that would not fit in a toddler's mouth. Our set of 32 teeth is completed by wisdom teeth in our late teens or early twenties. **SB**

Why is there so much friction when a spacecraft enters Earth's atmosphere?

PHELIM O'NEILL, IPAD APP

A spacecraft in steady orbit is in a controlled fall, where it travels forward fast enough that the ground moves away at the same speed as the craft drops. At a low-orbit altitude of 200km, that speed is about 7.8km/s (17,500mph), and even the thin upper atmosphere generates a lot of friction when you hit it at that speed. The kinetic energy of all those high-speed collisions with air molecules is transferred to the craft's hull, so it gets hotter. By a handy mathematical coincidence, the peak temperature a spacecraft experiences during re-entry is equal to its orbital speed in metres per second. That's 7,800K (7,527°C), twice the boiling point of titanium, which is why spacecraft need ceramic heat shields. **LV**

NEXTMONTH

What is quantum superposition?

How far could the human eye see if the Earth was flat?

Why do parrots live so long?

Does 'double or nothing' betting actually work?

How many trees are needed to provide oxygen for one person?

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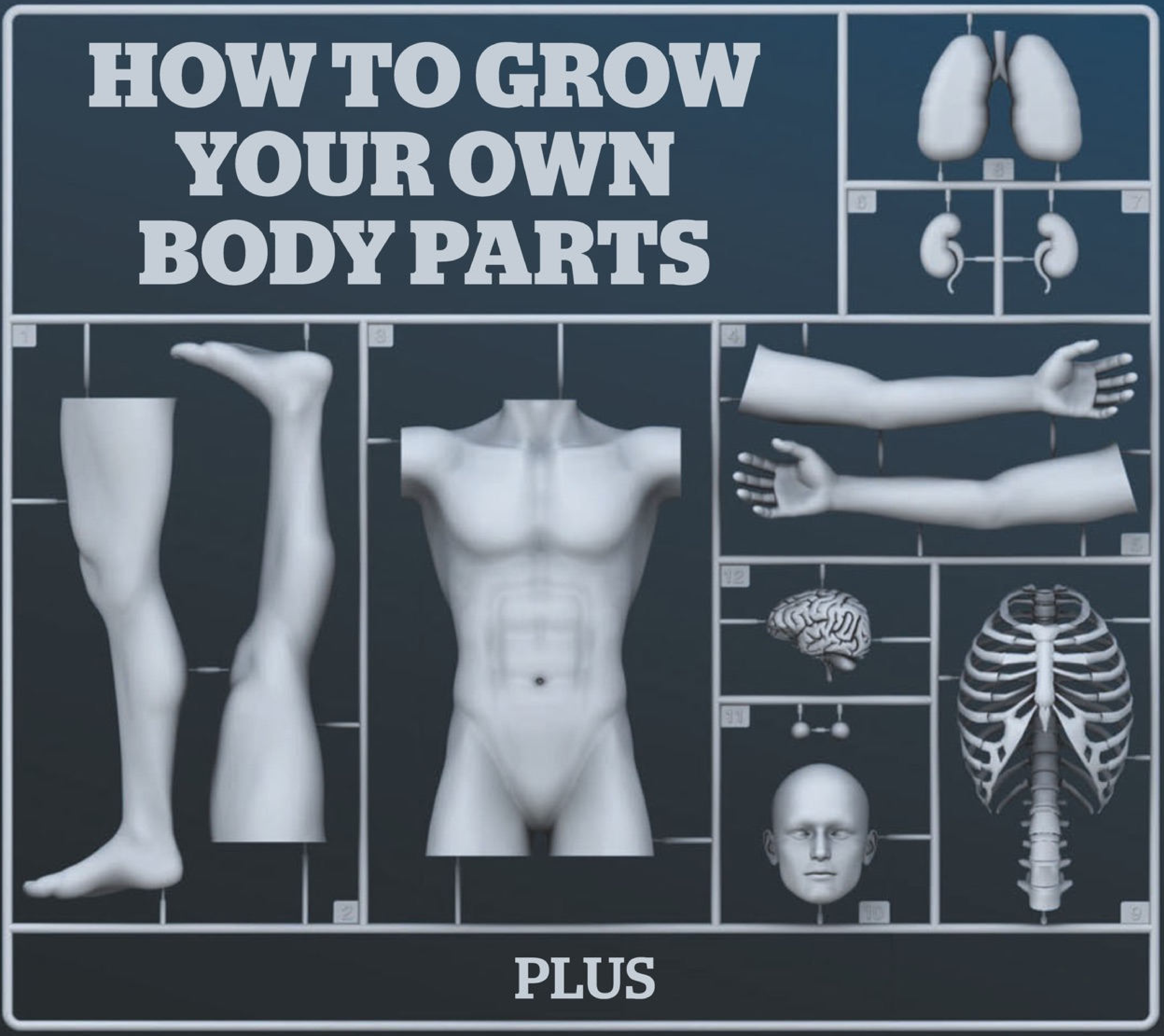

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The Guide

Everything for the clued-up consumer

Don't miss

Your very own spy drone 85
The most realistic racing sim money can buy 87
India's technological innovators 95
Why superstitions persist 100

Presenter Tom Bell investigates some gargantuan structures as they're sent to the scrap heap on BBC Two

ENGINEERING GIANTS

This new BBC series takes a rare peek inside the guts of some mega machinery

Scrapping an old car is tricky enough, but what happens when you need to get rid of something altogether larger, like a ferry or an airliner? *Engineering Giants* finds out by crawling inside such mechanical behemoths as they're pulled apart by the wrecking crews, piece by piece. Just like an autopsy, peering inside these machines at the end of their life provides an unparalleled insight into how they work.

The first episode goes inside a decommissioned gas platform in the North Sea as it's ripped from its foundations and taken back to the same shipyard it was built in. It's a process that took several months and required the skills of the engineers that built the platform nearly 40 years earlier. "Like surgeons, they knew exactly where to make the right incisions," says series producer Lindsay Keith, "before a 250,000-tonne crane simply yanked the helipad platform off its feet." The crane will keep chipping away at the 10-storey feet that secured the platform to the seabed, to minimise environmental impact.

But before that happened, Lindsay and her camera teams were able to climb inside the platform to explain how gas makes its way from the North Sea to the gas hob in your kitchen.

"We used the data from the decommissioning process to create a scale glass model that illustrates exactly how the gas travels out of the ground, into the platform and out to the mainland," says Lindsay, who goes on to add that filming the show's presenters, Tom Wrigglesworth and Rob Bell, inside these cavernous spaces was the only way to convey a sense of their sheer size to the viewer.

"While filming the series, I climbed inside this enormous Boeing fuel tank, and you just can't imagine what's sitting right underneath you. You could fill up 3,500 cars with the volume of fuel that's carried by a 747," she explains.

Unlike the other machines in the series, the Boeing wasn't actually being decommissioned. Instead, 30,000 working hours were devoted to removing and inspecting every last nut, bolt and part. "This series is as much about the incredible people that have built, looked after and eventually taken apart these machines – in some cases, for their entire lives – as it is about the machines themselves," says Lindsay.

BBC TWO **Engineering Giants** *airs on BBC Two in July*

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The **Review** Squad

Paul Monckton
Paul is a freelance journalist specialising in digital imaging. On p90, he tries out the new generation of high-spec 'compact system' cameras.

James Witts
As editor of *220 Triathlon* magazine, James is an expert on physical fitness. So who better to put Nike's new FuelBand monitoring system to the test?

Professor Bruce Hood
Leading psychologist Bruce Hood has taught at Harvard and MIT. On p100, he considers a new book on 'magical thinking' and how we are all prone to it.

Timandra Harkness
Between appearances in comedy stage shows, Timandra ploughs through the TV and radio schedules to find the best in science programming.

Bill Thompson
This month our resident technology guru turns his attention to 4G, and how new technologies have to compete for bandwidth with the old.

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FLIGHT OF THE QUADROCOPTER

Take to the skies with the ultimate remote-controlled toy

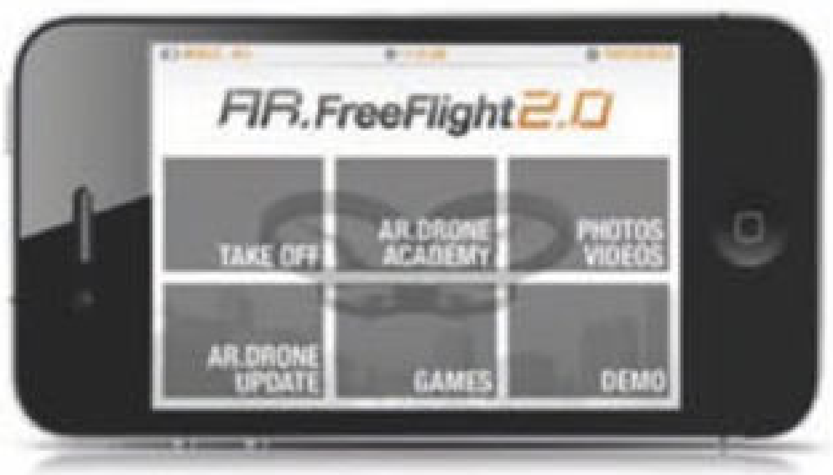
There's no denying it – this is a very big, expensive toy. But what a toy it is. Like something from an Orwellian dystopian future, the highly manoeuvrable drone generates its own Wi-Fi network, over which it sends a video feed from its camera to a phone or tablet display. The flight controls are then overlaid over this bird's eye view.

You might be thinking that squeezing flight controls for a 'copter on to a small screen would be tricky, but the piloting app makes use of the phone's accelerometers and gyroscope to fly the Drone as you tilt your handset around. The previous version of the AR.Drone was tricky to keep in the air, but this new one boasts a much smarter processor (a 1GHz ARM chip) that takes care of dozens of calculations to make sure it doesn't take a nose-dive. It's also loaded with pre-programmed tricks so even the most calamitous pilots can pull off a barrel roll.

Once you're comfortable flying it around, the augmented reality games provide hours of extra fun. These insert virtual obstacles and enemies into the real world through your phone's screen. For instance, one game has you shooting virtual missiles to take out alien spacecraft. Or if you want to use it as an actual spy drone, the new camera also records at a higher resolution (720p) – so you'll capture whatever you're peeking at in finer detail.

Spying aside, with its hi-res images and smart motion controls, this is probably as close as you're likely to come to flying an actual helicopter. The AR.Drone 2.0 is piloted via an iOS device, but there's Android support arriving soon.

Parrot AR.Drone 2.0
Price: £279.99
Info: ardrone2.parrot.com



The iPhone becomes your virtual cockpit with intuitive touch screen controls

Objects of desire

In the dock

If you've got an iPad, iPhone or iPod and want to connect it to your existing gadgets around the house, then this dock will play the middle man. It connects to your TV via HDMI, enabling you to watch YouTube on the set for instance, or you can connect it to your speakers via various audio outputs. A handy remote means you can operate it all from the comfort of your sofa.

Arcam drDock
Price: £200
Info: www.arcam.co.uk

Mighty mouse

It's a wireless mouse, only without any environment-killing batteries. Instead, the Genius DX-ECO gets its juice from a gold ultracapacitor, which stores a small amount of electricity. In this mouse's case it's enough for a day's use. This may seem brief, but it only takes three minutes to charge it back to full capacity.

Genius DX-ECO
Price: £29.98
Info: www.geniusnet.com

Air support

Inflatables don't usually get us excited at *Focus*, but with festival season in full swing this clever design piqued our interest. In place of fiddly poles and tubing, this tent uses toughened, inflatable tubes as its frame, which take a couple of minutes to pump up. Just watch out for hedgehogs.

Vango AirBeam
Price: From £225, sizes vary
Info: www.vango.co.uk

Racing ahead

If you love games, then this pod will be your personal nirvana. The TL1 simulator houses a 180º spherical projector, which pumps an image on to a curved surface. Inside is a motion-simulating race seat equipped with pedals and a steering wheel. Racing fans will be especially happy as it was created in partnership with the Somerset-based Ariel Motor Company, maker of the high performance Ariel Atom sports car, to recreate the sensation of driving a high-powered vehicle.

TL1 simulator
Price: TBC
Info: www.motionsimulation.com

Screen scrawler

This pen effectively turns any laptop screen 16 inches or smaller into a stylus-based touchscreen. A widget that snaps on to the side of the display pinpoints the pen's location using ultrasound and sends this data to your computer. It can be used to create hand-drawn sketches or even notes when combined with handwriting-recognition software.

PT' Pen
Price: $199 plus PnP
Info: www.baldtechnologies.com

Cutting-edge photos

While we're not entirely comfortable with the idea of a trip where you'd need a skinning knife, a nail file and a camera tripod, we can't deny that this multi-tool could be very handy. With two rubber-legged feet and weighing 340g, this pen-knife makes a sturdy, pocket-friendly tripod for an iPhone or camera for when you're out and about, err… skinning things.

Gerber Steady Tool
Price: £76.49
Info: www.gerber-store.co.uk

Could this watch change your life?

The Nike+ FuelBand aims 'to make life a sport'. **James Witts** straps one on to test its body-changing claims...

What is it?

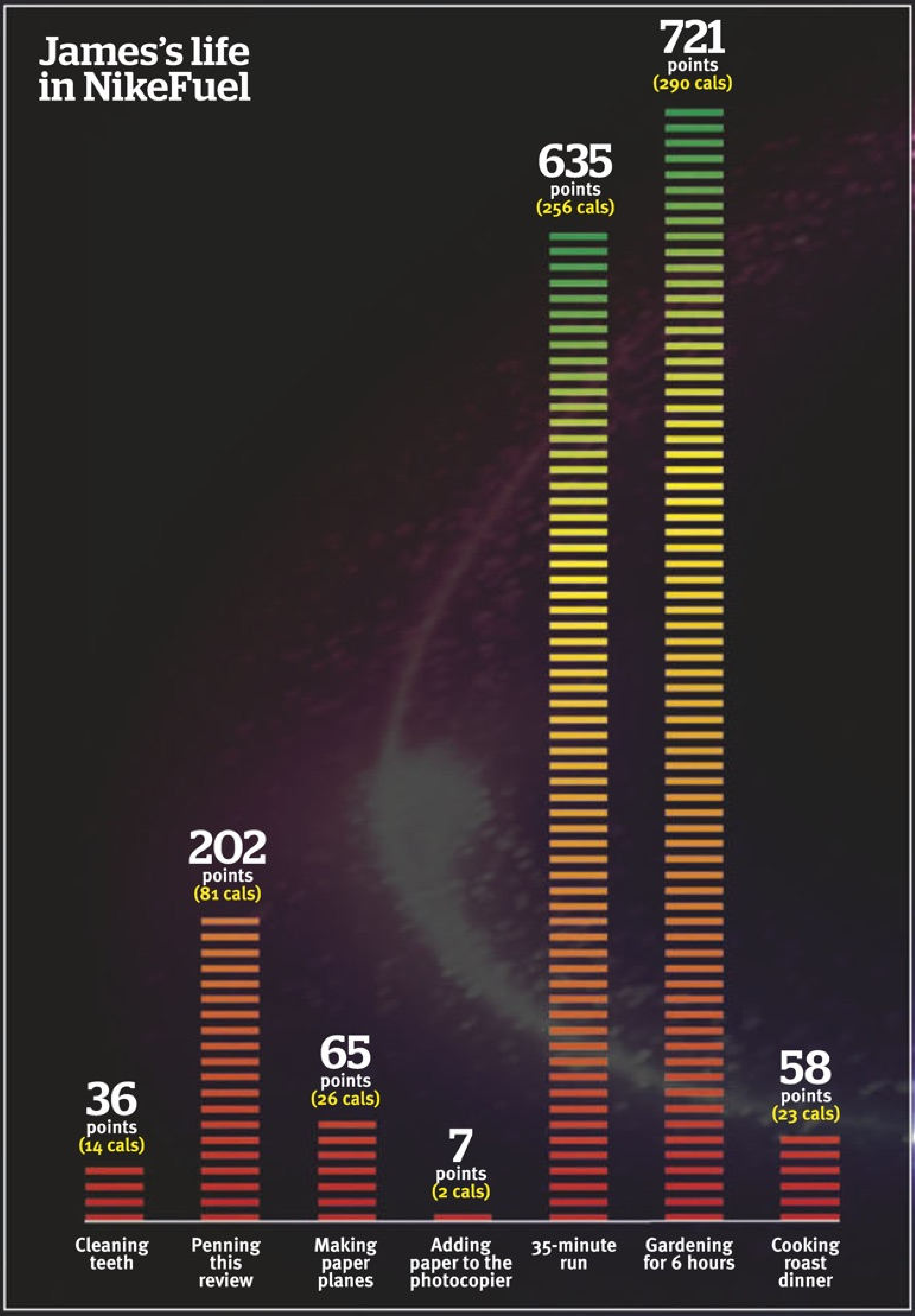
It's the US sporting behemoth's latest attempt to carve itself a niche in the lucrative training tool market. Nike's unique take on cutting fat and boosting power stems from NikeFuel, its 'revolutionary' new fitness measurement system. In short, whether you're break-dancing, skipping or putting out the rubbish, the strap will recognise this and reward you with NikeFuel points. All the techy stuff is stored within a sleek, stylish rubber band that's secured around your wrist by a metal clasp.

What does it do?

Each day you set yourself a NikeFuel target via either a free FuelBand app on your iPhone or by downloading the Nike+ Connect software. Aiming for 3,000 NikeFuel points is a reasonable target to set yourself; 6,000 and you'll be chasing Jessica Ennis around the racetrack, as one calorie burnt scores you roughly 2.8 NikeFuel points. White LEDs reveal your current score, while a further 20 LEDs flow from red to yellow to green to chart the progress you've made towards your daily goal; the final green LED indicating 100 per cent completion. Via a press of the button, it also measures calories burnt, steps taken and tells the time. And once that time hits midnight, the FuelBand resets to zero and you begin your next challenge.

What technology is involved?

It's all down to 3D accelerometers within the band. These devices measure the force of acceleration to whatever object they're attached to, and the 3D aspect means it measures movement in three planes – up and down, sideways, and back and forth. It works in sync with 'oxygen kinetics', the rather grandiose term for algorithms that, in this case, attribute NikeFuel points to various movements. Battery life is pretty good at three to four days.



WWW.STUDIO4PHOTO.CO.UK

PRICE: £139.99
INFO: www.nike.com/fuelband

What's the point?

Nike feels that calories burnt is simply too staid and small a measurement, supposing instead that many will maintain motivation if the points system is more ostentatious. It's the same template applied to computer games. After all, would *Pac-Man* have been so popular if you'd only scored one point for consuming a vulnerable ghost? The aim is to create an active online community of FuelBanders who unite to chase collective goals. Hit 10,000 NikeFuel points as a team for the day and you all receive an image of a trophy. Calm that beating heart…

What are the cons?

If your arms are doing something whereby they're relatively static, like cycling, it won't register. And despite its rubber casing, it's not waterproof, so no swimming. Also, if a slovenly sofa-lover shakes the band around in one hand while consuming their own bodyweight in cheese with the other, they'll reach their daily goal. That hard rubber means it's not particularly comfortable either, especially on long runs when you sweat a lot. And there's only an app for iOS devices, though we're assured an Android version is coming.

Should I buy one?

For anyone who regularly exercises already, it's too gimmicky. Instead, if fitness defines you more than a Bakewell tart, go for the Nike TomTom Sportswatch with GPS capacity. It's at a similar price point and measures speed, distance run, and pace. However, for sedentary types it could provide a source of motivation. And we're always a sucker for a pretty chart, so the online analysis of your day, week, month and so on receives the thumbs up. Its simplicity, flashing lights, large points scoring system and trendy aesthetic mean that it could be successful in encouraging children to get active. But that virtuous potential is ruled out by the prohibitive cost.

How it works

① **Go to nikeplus.com/setup, download the Nike+ Connect software (Mac and PC available) and create an account. Set your daily goal, strap on the Nike+ FuelBand and get active…**

② **Accelerometers sit on a flexible circuit board within the polymer casing. When your wrist moves, these detect the speed of acceleration in three planes of movement. Via a series of algorithms, the FuelBand translates these figures into calories burnt, NikeFuel points and steps taken.**

③ **Time for analysis. Re-link the FuelBand to your PC or iPhone. Here you can discover if you reached your goal, and find out at which parts of the day you were most active. It's all conveyed via charts, making your choice of lifestyle clear to see.**

Cutting-edge compacts

Compact system cameras offer the image quality of a DSLR at a fraction of the size and weight. **Paul Monckton** tests four of the best…

What's a compact system camera?

It's a new type of camera that, at the moment, lacks strict definition – which is what makes them so exciting, because there's a huge variation in size, features, quality and price. The point is that they're easier to carry around than DSLRs, offer you more control than a standard compact and give you the option to change lenses. They're so small because they've done away with the optical viewfinder and mirror system found in a standard DSLR. This means the lens can be closer to the image sensor and that, in turn, allows for smaller and lighter lenses. Altogether, this delivers a compact system camera that offers the quality and flexibility of a 'full-size' camera with none of the backache.

Why would I want one?

Compact cameras can be great for quick snapshots, but in low light or with fast-paced action they just aren't powerful enough. If you've ever wanted more control over your photos or fancied using a zoom lens, but don't really want to be burdened with the bulk of a DSLR, then a compact system camera could be just right for you. They're smart, too: most come laden with software to help you take great shots without having to think about it too much. They're also much less conspicuous than a DSLR, so you could potentially snap away unnoticed in situations where a DSLR might draw unwanted attention.

Do I need to buy lenses?

All of the cameras tested here come in a series of packages with different lens options. Sticking with the standard kit will almost certainly give you better image quality than a standard compact camera, but you should look at the lens selection available before buying. There's no single lens that can do everything – even if there were, it would be arm-wrenchingly heavy and comically big. If you want to take pictures of wildlife, for example, make sure the camera you're buying is compatible with a serious zoom lens.

WWW.STUDIO4PHOTO.CO.UK

What we tested

Ease of use for beginners
If you know little about photography, how easy is it to pick up the camera, shoot and get some decent shots? Does it help you learn as you go?

Ease of use for pros
How easy is it to use your knowledge of photography to make the camera do just what you want it to do? Does it have a good range of lenses and accessories?

Physical design and ergonomics
The camera's physical construction should be worthy of the often high asking price, while controls should be easy to use.

Picture quality
We're looking for excellent picture quality in a variety of shooting conditions. Can the camera cope with fading light, and freeze fast-moving action?

Fujifilm X-Pro 1

£1,299 (body only), £1,894 (inc. 35mm lens);
www.fujifilm.eu/uk

Weight: 400g
Dimensions: 140x82x43mm
Max shooting speed: 6fps
Sensor: 16-megapixel X-Trans, APS-C size
LCD: 3-inch, 1.23 megapixels
ISO range: 200–6,400 (up to 25,600 in extended mode)
Video: 1080p at 24fps, stereo sound
Battery life: 300 shots

+

Truly a photographer's camera, the X-Pro 1's all-metal body and superb build quality are reminiscent of the classic, and prohibitively expensive, Leica cameras beloved of the professional photojournalist. Inside, Fujifilm's specially-developed X-Trans sensor uses a cutting-edge new image capture technology which takes impressively crisp pictures that can rival the very best available from DSLRs today, even in low-light conditions.

It's the only camera here to offer a true optical viewfinder – which will keep enthusiasts happy – and better still, this can change like magic into a digital one at the flick of a switch and overlay all sorts of information on your image if needed.

−

Compared to a Leica M9's £5,000 price tag, the X-Pro 1 looks like a bargain, but back in the real world it's more expensive than a DSLR such as Canon's EOS 7D, which is more versatile. There's no built-in flash and only three Fujifilm XF lenses are available. They deliver excellent quality, but none are zooms. You can put the camera into a fully auto mode, but there's no built-in help for beginners and there are no selectable scene modes for portraits or landscapes.

Build quality: ●●●●●
Picture quality: ●●●●●
For beginners: ●●○○○
For pros: ●●●●○
Overall: **16/20**

Nikon 1 V1

£580 (inc. 10-30mm lens), £550 (inc. 10mm lens);
www.nikon.co.uk

+

Beginners will find this camera very easy to use, thanks to its simplified controls and built-in picture modes. It has a dedicated button to start capturing full HD video and you can shoot stills without interrupting recording. The V1 is also capable of some impressive time-bending stunts, shooting up to 60 photos in a second and producing super slow-motion video. It's incredibly fast at focusing and it will even pick your best shots from a series, using algorithms that evaluate which is most in focus.

Its small image sensor enables the use of much smaller lenses, so you can easily take a selection with you, and you can also use full-size Nikon lenses via an optional adapter.

−

Seasoned photographers may find using this beginner-friendly camera frustrating. More advanced, creative and manual controls *are* available, but you have to search through a series of menus to find them.

The small sensor also offers the lowest image resolution of the four cameras and hampers low-light performance, so picture quality gets worse as the daylight fades. It means you'll have to pay extra for the optional flash gun.

Build quality: ●●●●○
Picture quality: ●●●○○
For beginners: ●●●●●
For pros: ●●○○○
Overall: **14/20**

Weight: 294g
Dimensions: 113x76x43.5mm
Sensor: 10-megapixel, CX size
LCD: 3-inch, 921,000 pixels
ISO range: 100-3,200 (6,400 in extended mode)
Video: 1080i at 60fps, 1080p at 30fps, 640x240 at 400fps, 320x120 at 1200fps
Battery life: 350 shots

WWW.STUDIO4PHOTO.CO.UK

Panasonic DMC GX1

£469.95 (body only), £474.95 (inc. 14-42mm lens), £649.95 (inc. 14-42mm power zoom lens); **www.panasonic.co.uk**

Weight 272g
Dimensions 116x68x39mm
Sensor: 16.6-megapixel, Micro Four Thirds size
LCD: 3-inch, 460,000 pixels
ISO range: 160-12,800
Video: 1080i at 50fps, stereo sound
Battery life: 300-340 shots

+

The GX1 is an excellent all-round camera, with superb build quality and a full set of features that will delight beginner and veteran alike. It's very small and light, yet crams in a touchscreen interface that lets you focus on your desired subject simply by tapping it on the screen. There's an electronic viewfinder, too.

Despite its tiny dimensions, it contains a larger and more powerful sensor than the Nikon and is able to deliver more detail and better results in low light. However, the sensor is still small enough to allow the use of small, light Micro Four Thirds lenses, of which there are many available. It might not shoot quite as quickly as the Nikon, but it can still manage up to 4.2fps at full 16-megapixel resolution.

−

The smaller sensor is considerably better than that sported by the Nikon 1 V1, but still can't match the performance of the larger versions found in the Fujifilm and Pentax cameras. Image quality, while excellent for a camera of this size, isn't quite up to the standard of the Fujifilm or Pentax models either.

The DMC GX1's small button size also makes using its many control buttons and dials a little more fiddly than it would be on a larger camera.

Build quality: ●●●●○
Picture quality: ●●●●○
For beginners: ●●●○○
For pros: ●●●●○
Overall: **15/20**

Pentax K-01

FOCUS
BEST BUY

£599.95 (body only), £679.95 (inc. 18-55mm or 40mm pancake lens); **www.pentax.co.uk**

+

Part toy, part breezeblock, the K-01's looks are sure to polarise opinion, but with chunky controls and a rubberised grip, it's comfy to hold and easy for the more sausage-fingered of us to operate. Looks aside, it's very much an SLR with the viewfinder removed, in both form and function, and should be easy for anyone familiar with an SLR to get to grips with. Novices can turn the mode dial to 'Auto', or select from 19 scene modes, but advanced modes are easily accessible if you want them.

The K-01 is designed to use any of Pentax's existing SLR lenses, which means you get an enormous range to choose from. It's quick, responsive and above all delivers great image quality.

−

There's no eye-level viewfinder on the K-01 and no option to add one, so you'll have to work exclusively from the LCD screen, which can be a little cumbersome at times due to the camera's considerable size and weight.

Full-size lenses are more widely available than those specially designed for compact system cameras, but they're also bigger and heavier. Your K-01 kit bag will therefore be almost as heavy as that of an SLR.

Build quality: ●●●●●
Picture quality: ●●●●●
For beginners: ●●●●○
For pros: ●●●●○
Overall: **18/20**

Weight: 561g
Dimensions: 122x79x58mm
Sensor: 16-megapixel, APS-C size
LCD: 3-inch, 921,000 pixels
ISO range: 100–12,800 (up to 25,600 in extended mode)
Video: 1080p at 24, 25 or 30fps, stereo sound
Battery life: 540 shots

Make the most of your Camera

Accessories to help you take great shots with your camera

GIOTTOS VITRUVIAN RANGE

The Vitruvian 9225 features aluminium reverse technology legs that fold through 180º, meaning it folds up to only 33cm long! Complete with ball & socket head, quick release plate, spirit level and pan lock, it can hold up to 4kg making it the perfect companion for aspiring CSC photographers. Larger sizes and lightweight carbon fibre options available.

PRICE: SRP £190
www.giottos-tripods.co.uk

ACME MADE UNION ULTRA-ZOOM

Protect in style! The Union Ultra-Zoom has a sleek silhouette with enough room to fit compact system cameras with their attached kit lenses, plus a few small accessories like an extra battery or SD Card. Also features a quick-access lens pocket, adjustable shoulder strap and rear belt strap.

PRICE: SRP £30
www.acmemade.com

LOWEPRO EVENT MESSENGER

Capture life's moments with an Event Messenger 100 from Lowepro. Designed for your CSC kit it features a comfortable shoulder strap, front, reverse and side pockets for accessories or personal items and even includes a dual-mode flap design that can be switched between security and quiet working modes.

PRICE: Retails around £39.99
www.lowepro.com

JOBY GORILLAPOD HYBRID

The GorillaPod Hybrid features flexible, wrappable legs for hands-free shots and rock-solid stabilisation on most surfaces. The integrated ball head with 90º tilt and 360º pan helps you capture professional images without the hassle of a full-sized tripod. Holds up to 1kg but alternative sizes are available.

PRICE: SRP £35
www.joby.com

Spencer Kelly

Resourceful India

It's a humid 35° and Narayanan, owner of 10 acres of farmland in Tamil Nadu, southern India, has just completed his daily walk of several miles to his fields, in order to switch on his electric pumps and water his crops. But when he hits the button, there's no gushing sound from the other side of the field. Once again, there's a power cut and his entire journey has been wasted.

Fortunately, Narayanan has recently taken delivery of a small box from the company Nano Ganesh run by Santosh Ostwal. It contains the guts of a simple mobile phone. Hooked up to the pump, Narayanan can now simply dial up the box from his own mobile and switch the pump on remotely, saving him a wasted journey.

Santosh Ostwal with his mobile-operated pump device

It's my second time in India with the *Click* team, and on both occasions I've seen something the developing world does brilliantly – hacking together bits of existing tech to get things done. I previously visited a village with no running water, very little electricity and no mobile phones. Bizarrely, in the middle of the village square, an LED message board had been lashed to a tree with a rope. Why? Using a SIM card in the back, it displays text messages from family members who've moved away.

Both innovations are from small Indian companies that are working in areas the tech giants aren't interested in – those with next to no money to spend. Surely, it won't be long till these innovative companies start snapping at the heels of the rest of the world.

Spencer Kelly is the presenter of the BBC's technology show *Click*

How to...

SEND SENSITIVE DATA SECURELY

Cyber thieves are always on the hunt for your personal information. Stay safe online with these security tips

Split the message up

If it's good enough for spies, then it's good enough for us. If you have to send your password to a friend so they can log in to your Amazon or eBay account, then do so via two different messaging systems. Text them the password and then send an email with your username – you can split a link into two to share it securely too. One of your email accounts might be hacked, but it's unlikely that you'll have your phone tapped too.

Simple encryption

If you need to send a full file that you wouldn't want prying eyes to see, then using Dropbox.com is an easy solution. Handily, the site (though not the mobile app) encrypts everything you upload and download over a secure HTTPS connection. Register with the site, upload your file, then right-click the file and select Dropbox > Get Link. This will copy a shareable link for the file to your clipboard that you can then send to anyone you like.

Complex encryption

If you're really paranoid about someone else getting hold of your files, then your safest bet is to compress it into a zip file and password-protect it. Whether you use software like 7-Zip or WinRAR, right-clicking on a file will give you the option to compress or archive it. There's also an encryption mode that will attach a password to the file. The only downside is that your recipient will need similar software to extract the file.

Tech Doc's App Prescription

FileHound

iOS £2.49

Loading files onto your iPhone can be a right pain in the USB. This app gives you remote access to files on your PC to search and view them without going through iTunes. You'll need to install the streamer on your PC, but then you'll be able to edit documents from your phone and even stream movies.

Dream:ON

iOS 69p

Created by psychologist Richard Wiseman, this app offers to help you influence your dreams. It senses when you're dreaming by monitoring your movements in bed. Once you're in dreamland it plays a pre-selected 'soundscape'. A peaceful garden could have you picking flowers, for example.

THINKSTOCK

And the scariest uniform award goes to…

THE SECRET WORLD

PC

EA, £34.99, plus subscription

In the wake of the all-conquering massively multiplayer online (MMO) game *World Of Warcraft*, it's not hard to come by such a game with a fantasy setting. A fantasy world (elves, orcs) isn't a safe bet exactly, but it's one with proven success.

A contemporary setting is a rarity, and for this alone *The Secret World* should pique a PC gamer's interest. It's got the same glossy production values as *Star Wars: The Old Republic*, seen in cinematic cutscenes and engaging dialogue, but tells its story in the world of today. However, it's a world of today in which all the ancient myths and urban legends are true, but only the game's three powerful player factions know it. These are the zealous Templars, the ruthless Illuminati, and the sneaky Dragons.

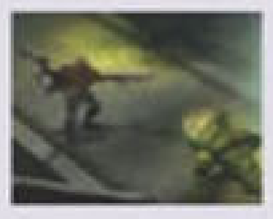
It's an alluring setup for players with fantasy fatigue: a world you know, featuring cities such as London, Seoul and New York, beset by nightmare creatures. Ever since the disappointment of *Hellgate: London*, a sub-par MMO in which demons plague the streets of the capital, I've been waiting for just that.

As is custom, players must pick a faction but, unlike in many an MMO, there are no discrete character classes. Instead, you select skills from a vast wheel of options as you make progress, piecing together a unique character to slay otherworldly monsters. It's an appealing approach to shaking up the safe old formula, and combat is designed to be more direct and immediate than is usual – making, hopefully, for an invigorating change of pace and scenery.

Egypt: great for pyramids, tombs and… dragon skeletons

ALSO OUT

HEROES OF RUIN



3DS

Square Enix

£24.99

A fantasy adventure, in which up to four players band together to gather precious loot on a quest to lift a curse on the kingdom's sphinx-like ruler. This might be a familiar experience on other platforms, but it's a fresh one on Nintendo's 3D handheld. And one with plenty of replay value thanks to its four classes of customisable hero and randomly generated dungeons.

ANARCHY REIGNS

PS3, X360

Sega

£34.99

This brawler puts you toe-to-toe with up to eight other fighters online. Disasters, both natural and man-made, wreak havok in its post-apocalyptic arenas. The cast contains both original cyborg characters and guest stars from other games by the developer, such as the catsuited witch Bayonetta. Combo moves and spectacular special attacks make for brash, bonkers action.

GAMESPRESS X4

Jane Douglas

Fund it yourself

Crowd-funding internet service Kickstarter has been making waves in the world of video games: big, splashy, valuable waves. When Double Fine studio head Tim Schafer used the service's site to court fan donations to fund a new game, the money tide came in faster and deeper than anyone had expected.

Initially, Double Fine sought $400,000 to make a point-and-click adventure game. The genre is not much in favour right now, so even this relatively modest sum might have been hard to attract from a traditional funding channel – say, a big-name games publisher.

The entirely non-traditional channel worked. Players forked out $3.3m for the game they wanted to play. Since then, studio Replay Games has similarly secured over $500,000 for a remake of a 1997 point-and-click *Leisure Suit Larry* game. And invitations to donate to new, offbeat projects are springing up all the time.

Giving publishers the cold shoulder: Kickstarter

In these early days it might seem this new funding model, with gamers investing directly in game makers they believe in, could finance not just a few pet projects or a neglected genre niche, but an entire industry. Look out publishers! You've been cut out of the picture.

But Kickstarter's success could easily be damaged by below-par games; players who have been burnt would quickly lose interest. People will already be wary after one Kickstarter project, the game *Mythic*, turned out to be a scam – raising $5,000 in pledges before the plug was pulled.

It's because of cases like this that Kickstarter will probably mean an invigorating splash of diversity, rather than a complete revolution in the way games are bankrolled.

Jane Douglas is section editor of GameSpot UK

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Bill Thompson

Battle of the airwaves

When next generation mobile phone networks finally roll out across the UK this year, it will make life much easier for people like me who spend a lot of time on the move. Long Term Evolution (LTE) or 4G mobile will give us faster web downloads, reliable streaming video and the ability to upload large files, as well as supporting serious online gaming on the go.

It's going to be a joy for everyone, except people living within around 2km of a 4G phone mast, who might find that the LTE signal interferes with their Freeview television signal. The part of the radio spectrum that LTE occupies is in the 'old' analogue TV area that was freed up by the recently completed move to digital terrestrial broadcasting. Somewhere between 500,000 and a million homes might be affected, and each will have to fit a small filter to their TV cable to correct the problem. For an estimated 10,000 homes even this won't be enough and they will have to give up Freeview and move to cable or satellite if they want to watch television.

The 4G network providers will pay to have the problem corrected, and many people will get free filters or have their costs covered, so all of this is really a bit of a non-problem that has been blown up out of all proportion in the newspapers. There was a similar fuss about the few people who had failed to heed the warnings when TV switched from analogue to digital in their area and missed a few episodes of Coronation Street.

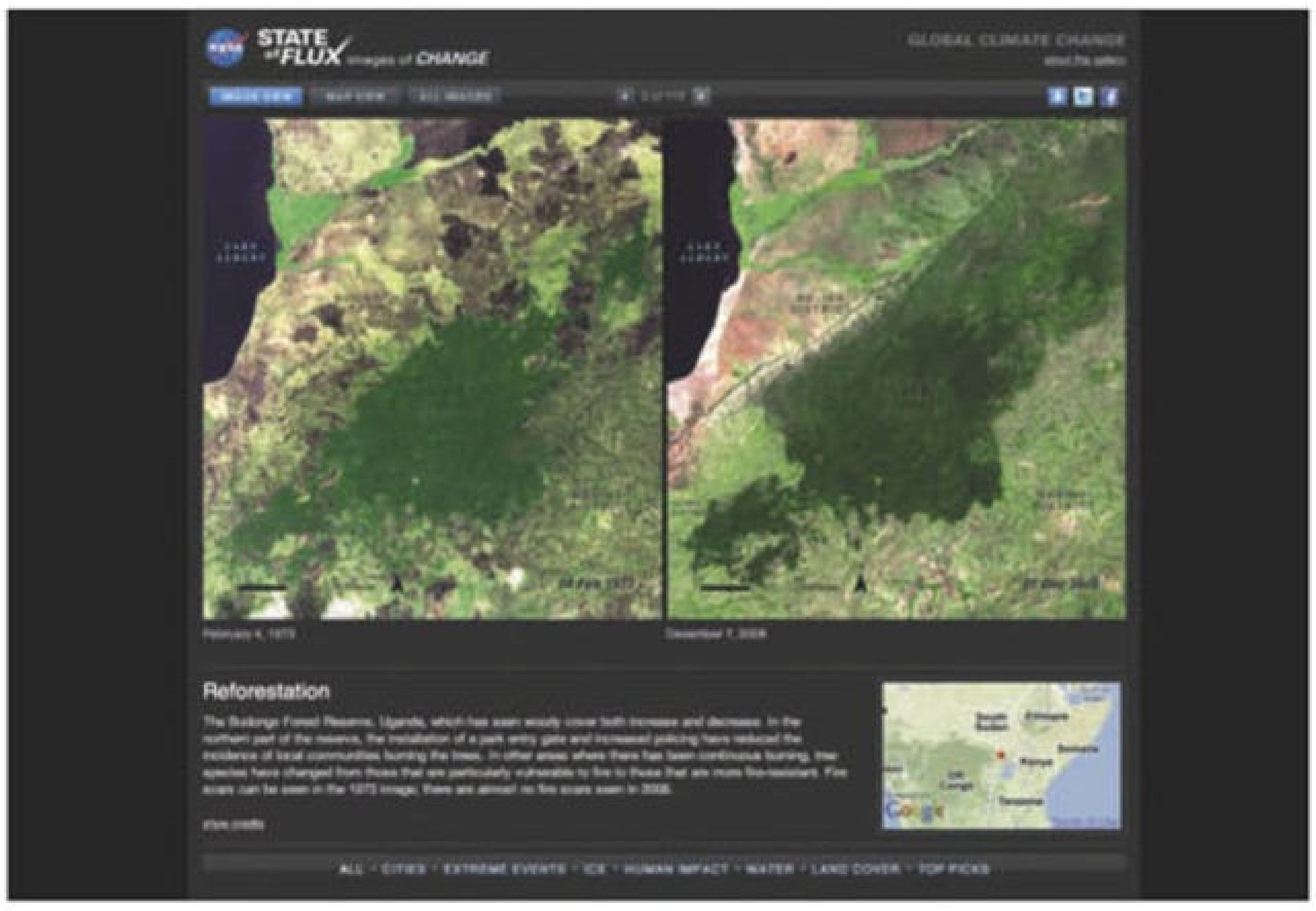
Of course if I had the choice I'd go for fast mobile over television any day, as internet access gives you everything that TV can offer plus a lot more. Even the most sophisticated TV service is still a special-purpose network that only does one thing well. Every time we introduce a new technology, service or product there will always be some who feel that the older way of doing things was superior, or who cannot easily make the transition to the new.

We tend to notice the transitions from analogue to digital, but the issue of Freeview's disruption by the rollout of 4G is about competing digital services and how they use the available radio spectrum. This is going to happen more and more in the future, since the rate of change of digital technologies is so rapid. The trouble is, we don't yet seem prepared for the hard choices that will have to be made to keep up with the pace of change.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

State of flux

climate.nasa.gov/sof



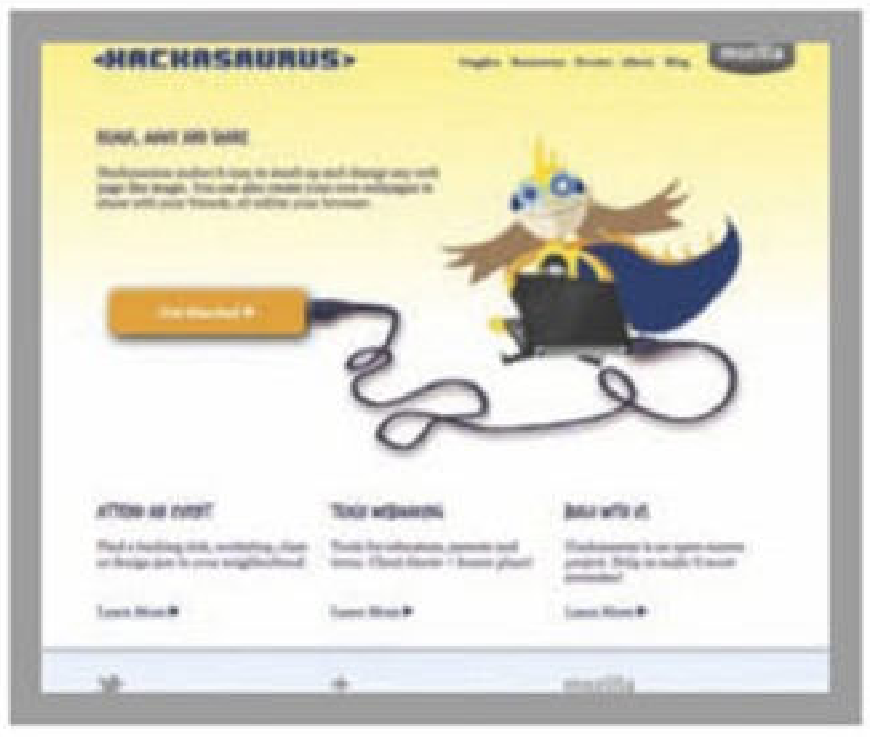
This astonishing gallery of photographs from NASA, with new images added each week, reveals how the Earth is changing. The same area is shown at different times, over periods ranging from days to centuries, and documents the effects of urban development, natural disaster and climate change.

The interface is designed to encourage exploration, offering a map view that lets you choose which area you want to see, as well as a gallery of before and after images. The pictures NASA has chosen are genuinely compelling, giving a real sense of how a landscape can shift.

For me the important ones are those that deal with the impact of global warming, as only someone who has no understanding of how science works can deny the validity of current theories that climate change is real and caused by humans.

WEB HACKS

Control the internet with Hackasaurus



What: Hackasaurus gives you a set of tools that show you the nuts and bolts of the internet, encouraging you to take more control of your online experience. These include a pair of online 'X-Ray Goggles' that let you examine other web pages, revealing the HTML code behind them, as long as you're using Chrome, Firefox or Safari.

Why: Knowing how the websites actually work can be a vital skill if you've come to depend on your web browser. The simple, interactive sections teach you how web pages are put together and show you how to make changes, which you can then publish online. It's a great starting point if you've ever aspired to make a website of your very own.

Who: Hackasaurus is an educational website from the Mozilla Foundation, the non-profit organisation behind the Firefox browser and many other open source software projects.

Where: www.hackasaurus.org/en-US

World Science Festival videos

http://worldsciencefestival.com/wsftv

The World Science Festival has been running since 2008, and in that time it's given a platform to many great scientists and major cultural figures – and many of these talks have been recorded. The videos are arranged by theme, with physics, maths and neuroscience well represented. They provide an engaging, well-considered selection of viewpoints on current research and scientific history.

Explore a scientific ocean drilling vessel

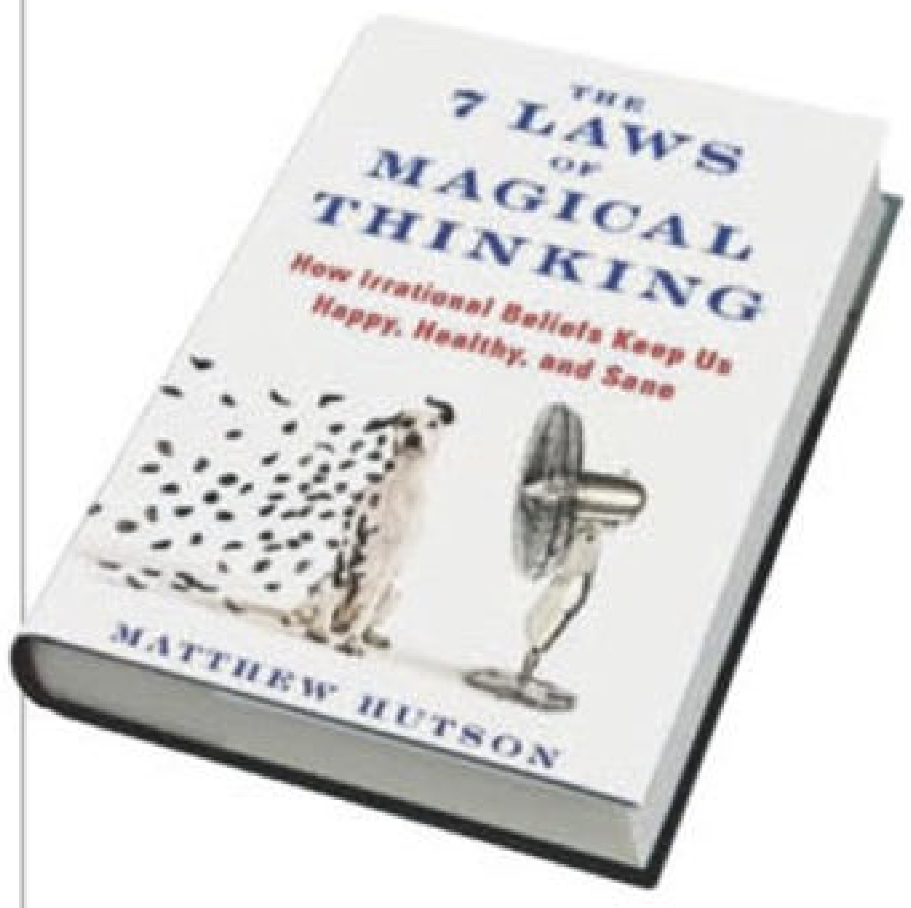
www.iodp.tamu.edu/labs/ship.html

JOIDES Resolution labs, accommodations, & drilling capabilities

Someone has gone to the trouble of documenting most of the interesting bits of an ocean-drilling vessel used for scientific research, and now you can explore it for yourself. Areas of the ship, like the bridge, science office and living quarters have been photographed and compiled into a virtual tour accompanied by detailed annotations. It may never replace being there with the spray in your face, but it's just enough.

The 7 Laws Of Magical Thinking

An engaging overview of our superstitions, says **Professor Bruce Hood**



How Irrationality Makes Us Happy, Healthy, And Sane
Matthew Hutson
Oneworld, £12.99
(pbk, 304pp)

Most of us think we're reasonable people, and not prone to believing nonsense. But the truth is that many of us do believe in some form of nonsense – ideas or practices that don't make any scientific sense. There is a variety of terms for such ideas, and Matt Hutson gathers them all together in *The 7 Laws Of Magical Thinking*.

He argues that we all believe in magic – be it luck, destiny, jinxes or life after death. Many will reject this accusation of woolly thinking, but Hutson skilfully takes us through principles of superstition that we may not immediately recognise as 'magical' thinking.

My favourite chapter is 'Objects Carry Essences', which refers to our strange attachment to certain objects. We treat original artwork as more valuable than copies, and we get emotionally attached, or otherwise, to sentimental items. Many of us wouldn't want to wear a murderer's clothing, for instance. It's as if these objects are imbued with the spirit of the previous owner.

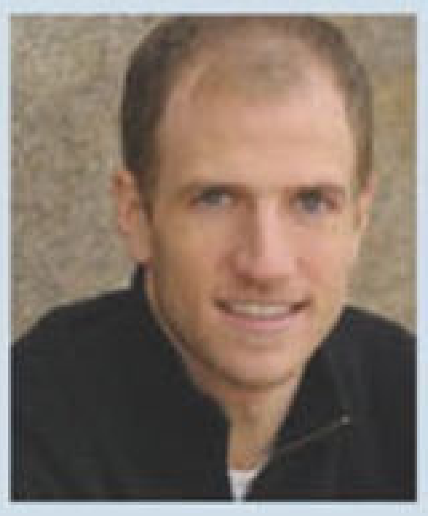
Two chapters deal with 'mind-body dualism' – the idea that our mind is separate from our body. If that were true, then natural laws would not control the mind, giving it all types of supernatural ability. Although magical beliefs are widespread in society, Hutson supports the view that they arise naturally from the way our brains have evolved to seek meaning and patterns – something akin to having a 'supersense'.

With such widespread magical thinking, you might wonder how we'll ever progress as a species. Fear not. As Hutson points out, magical thinking provides some real benefits: people who hold these beliefs are happier, healthier and hold a more positive outlook. This book is a remarkably creative synthesis of the science behind magical thinking, threaded through with a very personal narrative that engages the reader. ●●●●●

***Bruce Hood is a psychologist and author of* The Self Illusion**

Attachment to physical objects such as photos is, Hutson argues, a form of 'magical thinking'

GETTY



Matthew Hutson on *Magical Thinking*

Why did you decide to write this book?

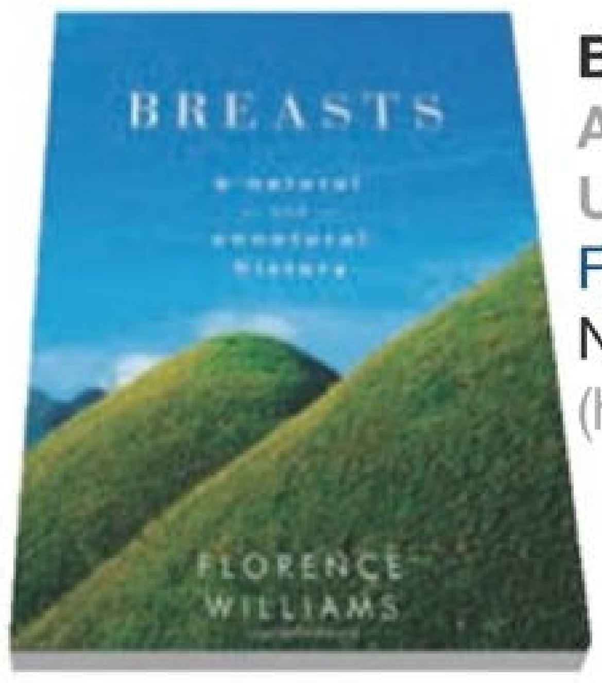
My initial motivation goes back to when I was a kid. I became an atheist and started wondering why smart people believe strange things. I went on to think about the nature of consciousness and studied cognitive neuroscience. So I've really been trying to get at how we construct reality in our heads. *Magical Thinking* highlights these quirky behaviours: it gets down to the core of how we judge cause and effect, or assess intentionality. And on top of that, there's an emotional component in how we find meaning in life.

What surprised you most?

I'd assumed magical thinking was necessarily bad. But just as there are white lies, it's not always best to have a completely accurate picture of reality – there can be benefits to magical thinking. For instance, rituals where people knock on wood or cross fingers: they do these things to feel lucky, which can actually help. In one study, subjects were given a golf ball and asked to make 10 putts. Half were told the ball was 'lucky', and these subjects were 35 per cent more successful.

Which part of the book was most challenging?

A lot of the questions just didn't have clear answers. So I would keep asking 'Why?' – trying to drill down to the origins of certain ways of thinking – and eventually you get to the point where there's no scientific consensus, or several possible answers. At times it felt like trying to decode human nature! What's been surprising is that most of the negative feedback I've had has been from fellow sceptics and atheists. Some people are offended by just the idea that they're not as rational as they would like to believe.



Breasts

A Natural And Unnatural History
Florence Williams
Norton, £16.99
(hbk, 352pp)

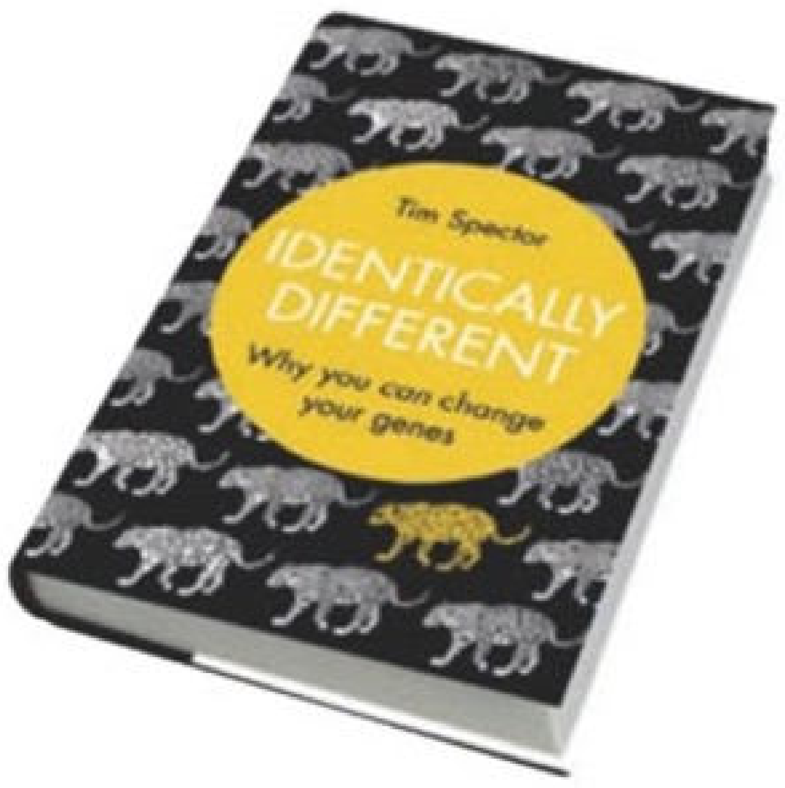
Breasts: many of us have them, many of us love them. But outside serious texts on breast-feeding and the numerous erotic portrayals of boobs, an in-depth discussion of the purpose and history of breasts has until now been absent. US academic and journalist Florence Williams has set out to rectify that with an engagingly written book that grabs your attention from the outset, with an opening sentence that lists the many different names people use to refer to breasts, including 'dingle bobbers'.

There's a fascinating focus on trying to separate issues of desire from the serious science around the evolutionary purpose of breasts, health and well-being (including cancer, contraception and HRT). Williams has a knack of detailing these complex scientific issues in a warm story that weaves in social and cultural aspects, and pegs the chapters around a woman's lifespan. Those sections where she draws on her own experiences, particularly with breast-feeding, are especially poignant and in places controversial, as she sets out to explore and critique the evidence around this often emotive topic.

The book is let down by a somewhat overly traditional view of sexuality: desiring breasts is considered something that only straight men do, while the experiences of transgender women are neglected entirely. Williams discusses social and cultural issues, but the book leans towards the science, with plenty of evolutionary and biological studies cited.

This isn't a self-help book about boobs, although aspects of it certainly are reassuring and informative. But if you're interested in a topic that we all have opinions about but frequently don't discuss – outside of jokes or the language of health care – then you'll like *Breasts*. ●●●○○

Dr Petra Boynton is a social psychologist and sex educator at University College London



Identically Different

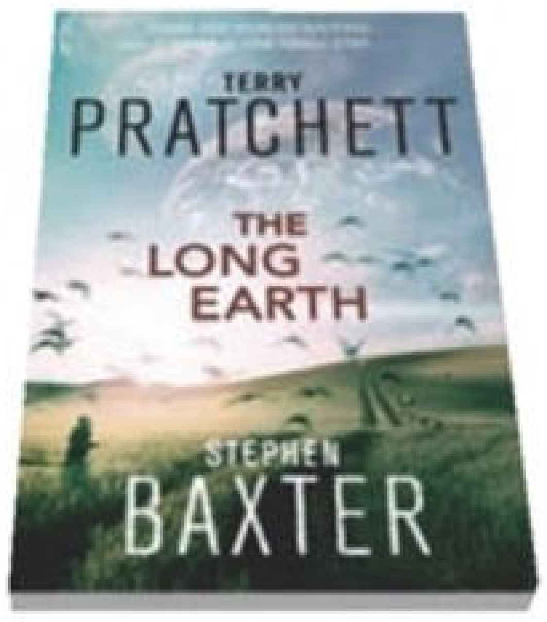
Why You Can Change Your Genes
Tim Spector
Weidenfeld & Nicolson, £20
(hbk, 336pp)

Mirroring the author's own shift from a strict focus on genetics to a perspective that also embraces epigenetics – the study of how the environment impacts genes – *Identically Different* is a journey through our evolving view of the human genome. It explores epigenetics through the phenomenon of identical twins.

Author Tim Spector has led previous large-scale studies of twins, so he's eminently qualified to write this book, and his style is fluid, lively and engaging. Even when covering well-trodden ground, such as differences in incidence of common diseases, he peppers his text with anecdotes and interviews with twins that instil the book with real human interest. There's also a beautiful chapter on research which suggests that many differences may not be due to our genes, but to those of the microbes that inhabit us.

At times the book ranges a little too widely, into topics such as sexuality, fidelity and religion. The molecular mechanisms that enable epigenetics are described so sketchily as to be unclear, and there are few attempts to distinguish controversial from well-established science. But despite this, and the odd factual inaccuracy, *Identically Different* is a fresh and thought-provoking book on how the environment affects genetics. ●●●●○

***Dr Nessa Carey is the author of* The Epigenetics Revolution**

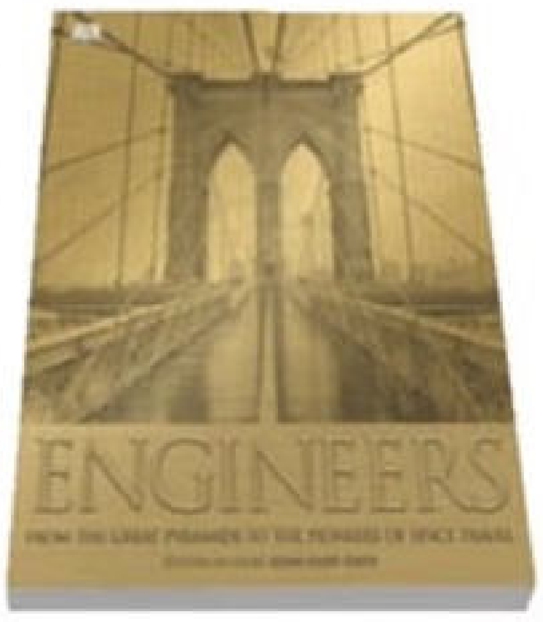


The Long Earth

Terry Pratchett & Stephen Baxter
Doubleday, £18.99
(hbk, 352pp)

How would society change if we inhabited a multiverse – if humans could simply step from this version of our world into other, often radically different iterations? This question underpins the first collaboration between *Discworld* creator Pratchett and science-fiction author Baxter. Centred on the adventures of explorers Joshua and Lobsang (human and AI respectively) as they travel ever further from 'Datum Earth', this scene-setting first novel in the series offers splendidly thought-provoking entertainment. ●●●●○

Jonathan Wright is a journalist and science-fiction expert

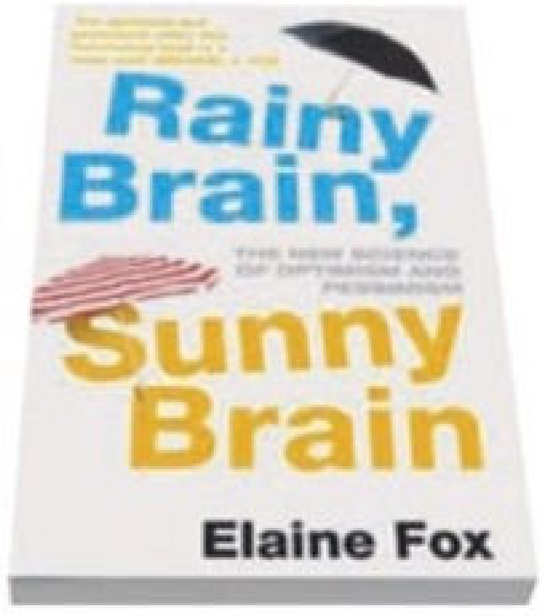


Engineers

Edited by Adam Hart-Davis
DK, £25
(360pp, hbk)

This weighty coffee table tome romps through mankind's engineering milestones, from the pyramids to the Large Hadron Collider and all points in-between. Buildings, bridges, transport, space travel – it's all here in one lavishly illustrated volume, with a well thought-out selection of stories, divided chronologically, highlighting ideas and minds that have shaped our world. Forget about putting up those shelves this weekend – relax with this book and see how the maestros do it. ●●●●○

Dallas Campbell is a presenter of* Bang Goes The Theory *on BBC TV



Rainy Brain, Sunny Brain

Elaine Fox
Heinemann, £12.99
(pbk, 272pp)

While some people are natural optimists, others prefer to ponder the gloomy side of life. In this book, Elaine Fox explains that both of these attitudes aren't necessarily hard wired in our brain. Using many examples from brain scanning and experimental studies, Fox shows that the natural state of the mind can be reprogrammed. Sometimes slightly heavy on jargon, the book sets out the increasing evidence that the brain can be rewired; pessimists might start seeing glasses half full rather than half empty. ●●●○○

Dr Chris Sinclair is a brain imaging scientist at UCL

SUMMER TO-DO LIST

The essential guide to the month ahead

3-8 JULY

EDITOR'S CHOICE

Summer Science Exhibition

The Royal Society's annual jamboree celebrates the best of British science. With tantalising exhibits like 'Insect birth control', 'Avalanche speed trap' and 'LOL! The science of laughter', this year's event looks well worth a visit. Panel discussions on forensics, dating, the senses and Olympic science are sure to make for a stimulating week.

Royal Society, London, free, royalsociety.org

UNTIL 8 JULY

LAST CHANCE TO SEE

Universe Of Sound

Listen to a virtual philharmonic orchestra playing Gustav Holst's famous *The Planets* as you walk through an interactive exhibit. Using the latest touch- and movement-sensing tech, you can compose your own score or join the orchestra as musician or conductor.

Science Museum, London, free, www.universeofsound.co.uk

10 JULY

The Most Human Human

Every year, the Loebner Prize challenges computer programs to fool us into thinking they are human. The 'chatterbot' that's deemed most human wins. As programmers get ever closer to completely fooling the judges, author Brian Christian explores the latest breakthroughs in AI, and how these are making us rethink what it means to be human.

Royal Institution, London, 7pm-8.30pm, £10, www.rigb.org

11 JULY

Imagining The Past, Remembering The Future

Sure, your memory's not what it used to be – but how good was it in the first place? Dr Charles Fernyhough explores how neuroscience is increasingly finding that memory is a fragile thing: easy to tamper with and often inaccurate. For instance, why are our earliest childhood memories always full of light? Or how can two siblings remember one childhood incident so very differently?

Royal Institution, London, 7pm-8.30pm, £10, www.rigb.org

14 JULY

Dublin Mini Maker Faire

This day-long fair, which is part of the Science Gallery's Hack the City season, hosts ingenious backyard inventors and scientists alike. There'll be software engineers with home-brewed games, designers making rapid prototypes with 3D printers and musicians playing musical hats. So there's bound to be something for big and small kids alike.

Science Gallery, Dublin, free, www.makerfairedublin.com

THE ROYAL SOCIETY, B EALOVEGA, THINKSTOCK, COLIN THOMAS, NATURAL HISTORY MUSEUM

17 JULY

Ben Miller

Who is he?
Comedian, actor and director Miller is best known for being one half of comedy duo Armstrong & Miller, stars of sketch shows on both Channel 4 and BBC One. You might also recognise him from TV drama *Death In Paradise* and *The Ladykillers* on stage.

What's his connection to science?
After studying natural sciences at St Catharine's College, Cambridge, he gained a PhD in quantum physics with a PhD thesis entitled 'Novel quantum effects in low-temperature quasi-zero dimensional mesoscopic electron systems'. No, we haven't a clue either.

What is he talking about?
Fortunately, not his PhD thesis. The talk is reassuringly entitled It's Not Rocket Science, and in it Miller will explain to us meagre-brains the science behind everything from black holes and global warming to the Large Hadron Collider.
Royal Institution, London, 7pm-8.30pm, £10, www.rigb.org

SPEAKER OF THE MONTH

19 JULY

Cutting Edge 2012: Behind Cycling

With British cyclists hoping to pedal to glory this summer, psychologist Dr Harry Rossiter reveals the legal tricks used by elite athletes to enhance performance, while Professor Louis Passfield examines the fine line between nutrition and doping. A world-class cyclist will also be on hand to answer your questions.
Free but booking required, Scottish Exhibition & Conference Centre, Glasgow, 7pm-8.30pm, free, www.rigb.org

19-27 JULY

Wrexham Science Festival

Join in dozens of live debates, experiments and interactive events, covering topics ranging from the chemistry of cocktails and the history of the electric car to the future of the internet, field archaeology, the science of soundwaves and the potential for lunar life. Plus, the Clockwork Universe explores the history of science from ancient Greece to Einstein through the power of music, while the Science Junkies reveal the physiology and engineering that go into the making of Olympic and Paralympic champions.
Glyndwr University, Wrexham, 19-27 July, prices vary, www.wrexhamsf.com

20 JULY

The Worst Journey In The World

Forget the Central Line or the M25 at rush hour. Trekking across the world's coldest continent in the middle of winter shows real dedication. Three scientists did just that to collect Emperor Penguin eggs, risking their lives in the process. In this talk by Douglas Russell, Curator in Zoology at the Natural History Museum, find out about the hardships they endured on their epic journey across Antarctica.
Natural History Museum, London, 2.30pm, free, www.nhm.ac.uk

24 JULY - 9 SEPT

Make It In Great Britain

You're sure to have heard someone say "Britain doesn't make anything anymore". Well, it's not entirely true. This interactive exhibition flies the flag by revealing success stories from the modern UK manufacturing industry, and explores the positive impact they've had on our lives.
Science Museum, London, until 9 September, free, http://makeitingreatbritain.bis.gov.uk

TV & RADIO

The month's top science programmes

Science Month

Eden,
Starts 2 July, 7pm

Get ready for a whole month of non-stop science on Eden, including the return of several hit series and some quality one-off documentaries.

Professor Brian Cox's *Wonders Of The Universe* series returns nightly for the first week. Dr Michael Mosley takes over with his *Histories of…* science and surgery from 9 July, and then *Inside The Human Body* from 16 July. Other series making a welcome comeback include *Finding Life Beyond Earth*, a two-parter using CGI and telescope images to investigate astrobiology, and Professor Marcus du Sautoy's *The Code*, an exploration of how the patterns of mathematics run through everything we do.

But if you can't bear to spend *all* of July indoors, at least make sure you catch some of the most entertaining documentaries of recent years. QI panellist Alan Davies asks *How Long Is A Piece Of String?* and finds the answer is more complicated than he expected, while comedian Ben Miller asks *What is One Degree?* – the temperature kind, that is, not the kind he earned from Bristol University's physics department. And finally, astronomer Maggie Aderin-Pocock poses the question: *Do We Really Need The Moon?*

Marcus du Sautoy's *The Code* and other science shows return on Eden

Shocking Lives

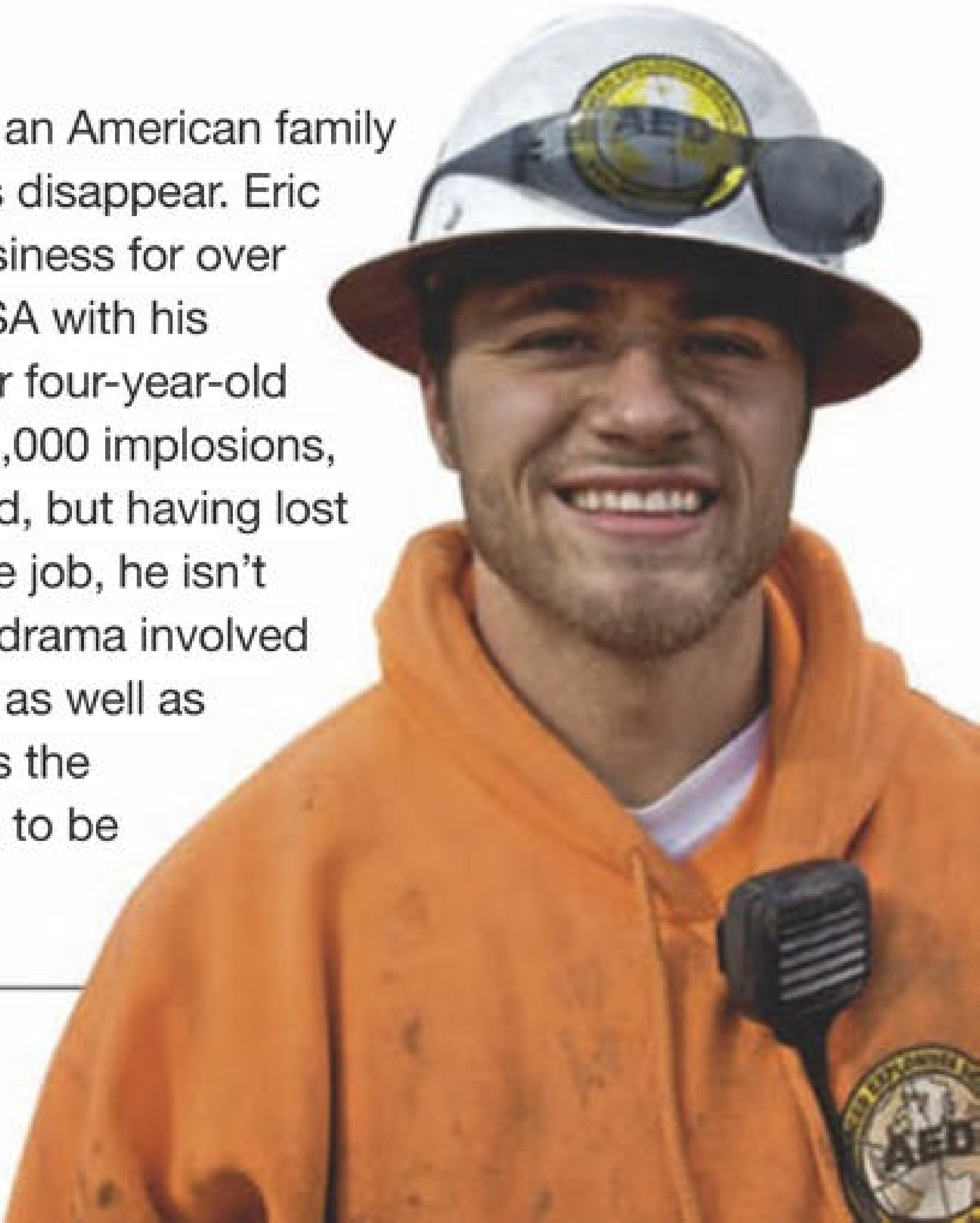
Discovery Home & Health
Starts 5 July, 10pm

Shocking Lives is a series of three programmes about ordinary people who face extraordinary medical challenges. Acromegaly is a condition that inflicts too much growth hormone on the sufferer, turning normal teenagers into giants of seven feet tall. Sometimes the only solution is risky surgery. In the second programme, Chandra Wisnu is so badly disfigured by skin tumours he's called The Bubble Man. But he doesn't want his children to face the same fate, so dermatologist Dr Anthony Gaspari travels to Indonesia in search of a solution. Finally, conjoined twins Maria and Theresa travel from the Dominican Republic to the USA for urgent medical treatment. Surgery to separate the girls may be their only chance of survival, but it carries enormous risks.

The Imploders

Quest
Starts 26 July, 9pm

Not the latest superhero movie, but an American family whose business is making buildings disappear. Eric Kelly has been in the demolition business for over 30 years, and now he travels the USA with his business partner (and wife) and their four-year-old daughter. He's never failed in over 1,000 implosions, and has a 100 per cent safety record, but having lost both his father and his brother to the job, he isn't complacent. There's clearly human drama involved in knocking down a 140-foot tower, as well as technical expertise. And then there's the 3,500-tonne arena in Texas that has to be taken down *without* explosives.



BBC, THINKSTOCK, DISCOVERY NETWORKS X5, KRISTOPHER FINNIGAN, NATIONAL GEOGRAPHIC CHANNEL X2

Radio

Amazonia: Keeping It Alive

BBC Radio 4
3 July, 11am

Brazil's economy may technically still be classed as 'developing' or 'emerging', but by the time Brazil hosts the Football World Cup in 2014 it will be the fourth largest in the world. Brazil also owns 85 per cent of the Amazon rainforest. To what extent can this be preserved, and how does that sit alongside the economic growth that is propelling Brazil from a poor nation to one of the 21st century's leading players?

The Nine Billion Names Of God

Radio 4 Extra
Starts 16 July, 6.30pm

John Shrapnel reads classic science-fiction short stories by Arthur C Clarke. In the first, eponymous tale, a Tibetan monastery's new computer threatens to answer the ultimate cosmic question and bring the Universe to a premature end. Four more Clarke stories throughout the week deal with themes of war, death and religious faith, concluding with *The Sentinel*, the short story which Kubrick and Clarke later adapted as *2001: A Space Odyssey*.

Science In Action

BBC World Service
Thursdays, 7.30pm, repeated Friday & Monday

In this weekly magazine programme, presenter Jon Stewart and his guests introduce the latest research from scientific journals, and discuss its potential impact on the world. Recent programmes have covered an intriguingly wide range of topics – from electric scooters to DNA-tagged fish, and from the future of space exploration and new treatments for breast cancer patients to the unexpected side benefits of natural disasters.

Death Machines

Quest
Starts 1 July, 10pm

Going straight for the dark side of human ingenuity, this series looks at the history of technology that has one purpose: to hurt, maim or kill a person. Some of the ways our forebears devised to inflict suffering and humiliation on the way to oblivion are appallingly clever. From crucifixion to the gas chamber, via the rack, the skull crusher and the brazen bull, we have not always put science to the service of good.

What The Industrial Revolution Did For Us

Discovery History
Starts 10 July, 10pm

Without it, you wouldn't be reading this magazine, or watching this six-part television series. But as historian Dan Cruickshank will show, we owe much more to the flowering of technical and scientific progress that shook the world over a couple of centuries. For example, John Harrison's solution to the longitude problem opened up international trade… but he also invented the toaster. No, we didn't know that either.

Python Hunters

Nat Geo Wild
Starts 2 July, 8pm

Shawn the snake expert, Michael the reptile breeder and Greg the cop love reptiles. Recent cold winters having granted them time off from python-tracking in Florida, they've made this TV series. Travelling the world to track down caimans in the Amazon and sea snakes in Australia might not be your idea of a holiday, but these guys do it so we don't have to.

Extreme Animal Attacks

Nat Geo
Starts 17 July, 8pm

If those pesky wasps are starting to spoil your barbecue, just imagine how much worse it could be. How about a random attack by randy elephants? Or being on the menu for a hungry carnivore in the Arctic or the Serengeti? As this series reveals, even apparently friendly animals can turn murderous: 'Horrific dolphin assault!' was not a phrase we ever expected to read. Fire that barbie up and eat them before they eat you.

London Games Unearthed

Yesterday
9 July, 9pm

Tony Robinson digs up the history behind London 2012. From a 6,000-year-old bronze axe unearthed during building work in east London to the Shropshire doctor whose concern for the health of the working classes led to the 1896 Athens Olympics, there is some quirky history here. A familiar format of CGI and engaging storytelling should appeal even to the sport-allergic.

Mythbusters

Discovery
Starts 23 July, 9pm

Jamie, Adam and the team return with a new season of the series that turns idle pub musings into dangerous stunts. Can you really do *anything* with gaffer tape? Are women superior to men? Could you glue a roomful of furniture to the ceiling? If watching this prevents just one drunk student from swathing himself in bubble wrap and jumping out of the window to find out what happens, it will be worth it.

BRAINTRAINING

Pit your wits against these brainteasers by **David J Bodycombe**, question-setter for BBC Four's *Only Connect*

Win
A copy of I Didn't Know That Vol 2 worth £12.99
I DIDN'T KNOW THAT VOLUME 2

Prize Puzzle

Place three more Xs in this grid so that each row, column and main diagonal contains exactly two Xs.

The first three correct entries drawn will win a copy of *I Didn't Know That Vol 2* (National Geographic, £12.99). Please send in your solution stating where you would place the Xs. For example, if you place an X in the co-ordinate A1, please write 'X in A1' and so on. Post your entry, marked 'Prize Puzzle 244', to: *Focus* magazine, PO Box 501, Leicester, LE94 0AA by 5pm on 26 July.

	1	2	3	4
A			X	
B		X		
C	X			X
D			X	

See bottom of p82 for terms and conditions. Congratulations to William Fay (Lincs), J Carrington (Rainham) and Colin McLean (Edinburgh) who all answered May's Prize Puzzle correctly to win a Maglite torch.

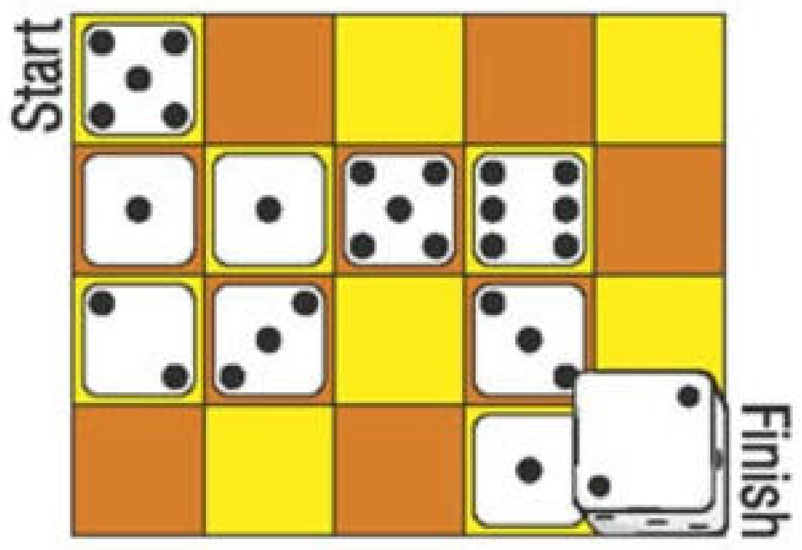
See *sciencefocus.com/winners* for previous winners and solutions

QUESTION 1

The Czech and Slovak word for 'PULL' is TAHAT. Why can this lead to confusion for shop customers?

QUESTION 2

A die has been rolled from square to square, with the upper face marked each time. However, one square is marked wrongly – which?

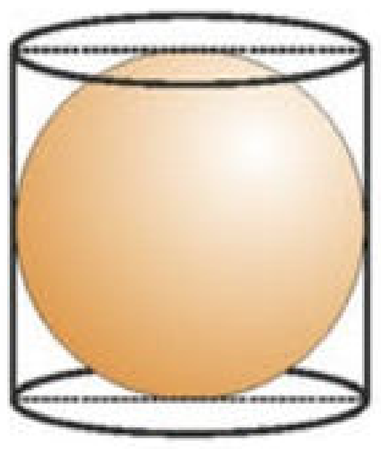


QUESTION 3

Which card of the diamonds suit in a standard pack clearly doesn't have half-turn symmetry?

QUESTION 4

What proportion of the cylinder's volume is outside the sphere?



QUESTION 5

Simone and Susan were playing tennis at the same time on the same court. Simone won three of the five sets. However, Susan also won three sets. How is that possible?

QUESTION 6

Pair up these letters in a logical manner. Which one is left over?

Y C O F

Q V G

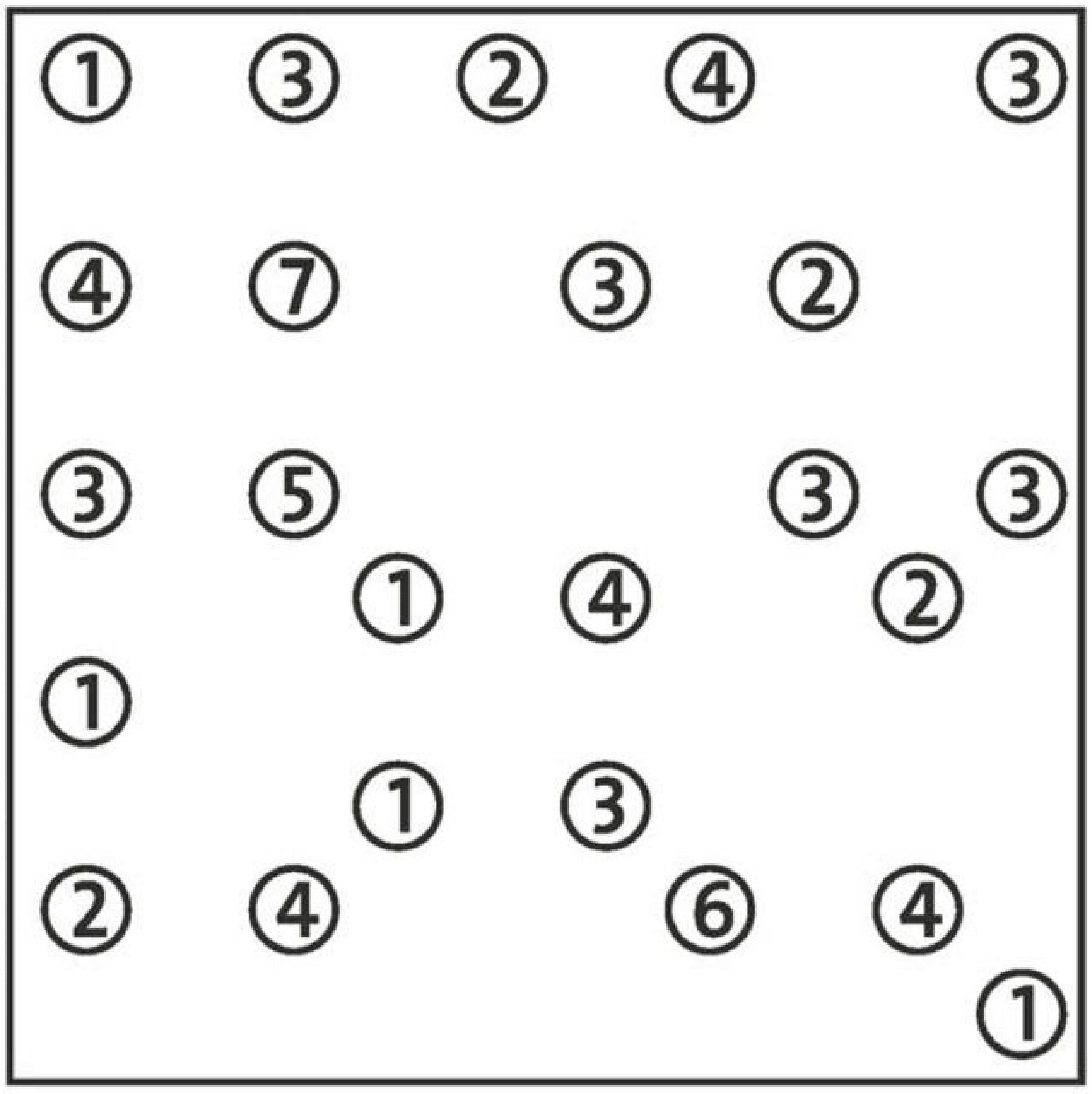
R E P X

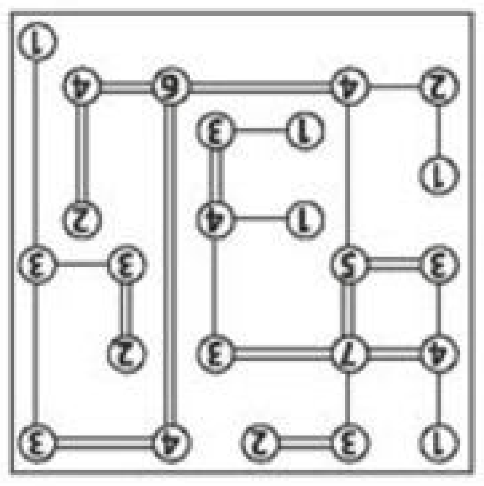
QUESTION 7

French sailors used petitions as a mild form of mutiny if they weren't happy with conditions on board a ship. How did they list their signatures on the petition so that no-one could be accused of instigating the rebellion?

QUESTION 8

The circles represent a number of islands that must be joined by bridges. All bridges must run horizontally or vertically, starting on one island and ending on the next. The numbers tell you exactly how many bridges are attached to that island. Each pair of islands could be connected by 0, 1 or 2 bridges in each of (up to) four directions. Bridges can't fly over other bridges or islands. At the end, all the islands must be connected – ie it must be possible to travel from one island to any other island.





Solutions

Q1) Because the word is symmetrical, it can be read as 'PULL' from both sides if 'TAHAT' is written on a glass door.

Q2) The 3-spot on the right should look like the one on the left.

Q3) The seven of diamonds. Its 'middle' diamond is offset from the centre, unlike the ace, three, five or nine.

Q4) One-third. [Compare: Sphere volume = 4/3 x pi x radius³. Cylinder volume = pi x radius² x height. Note that height = 2 x radius.]

Q5) They were both on the same side of a doubles match.

Q6) Y:X, F:E, O:Q, C:G, P:R (letters differ by one line) with V remaining.

Q7) They signed their names on a circular piece of paper so that no-one was at the top of the list. [The device was called a 'ruban rond' (round ribbon), from which we get 'round robin'.]

Q8) See illustration.

Quick Quiz

Test your knowledge of the wet stuff

QUESTION 1

Approximately what percentage of the Earth's surface is covered by water?

a) 70%
b) 80%
c) 90%

QUESTION 2

What name is given to the phenomenon where warm water sometimes freezes faster than colder water?

a) Kagera effect
b) Mpemba effect
c) Dodoma effect

QUESTION 3

Which of these moons of Jupiter is definitely not thought to harbour a subsurface liquid water ocean?

a) Callisto
b) Io
c) Europa

QUESTION 4

'Heavy water' is water enriched in which hydrogen isotope?

a) Protium
b) Deuterium
c) Tritium

QUESTION 5

Which of these places is home to an ice sheet?

a) Siberia
b) Iceland
c) Greenland

QUESTION 6

On top of Mount Everest, what is the approximate boiling point of water?

a) 70°C
b) 100°C
c) 130°C

QUESTION 7

Which of these terms describes a type of dehydration?

a) Isotonic
b) Hydratonic
c) Oxytonic

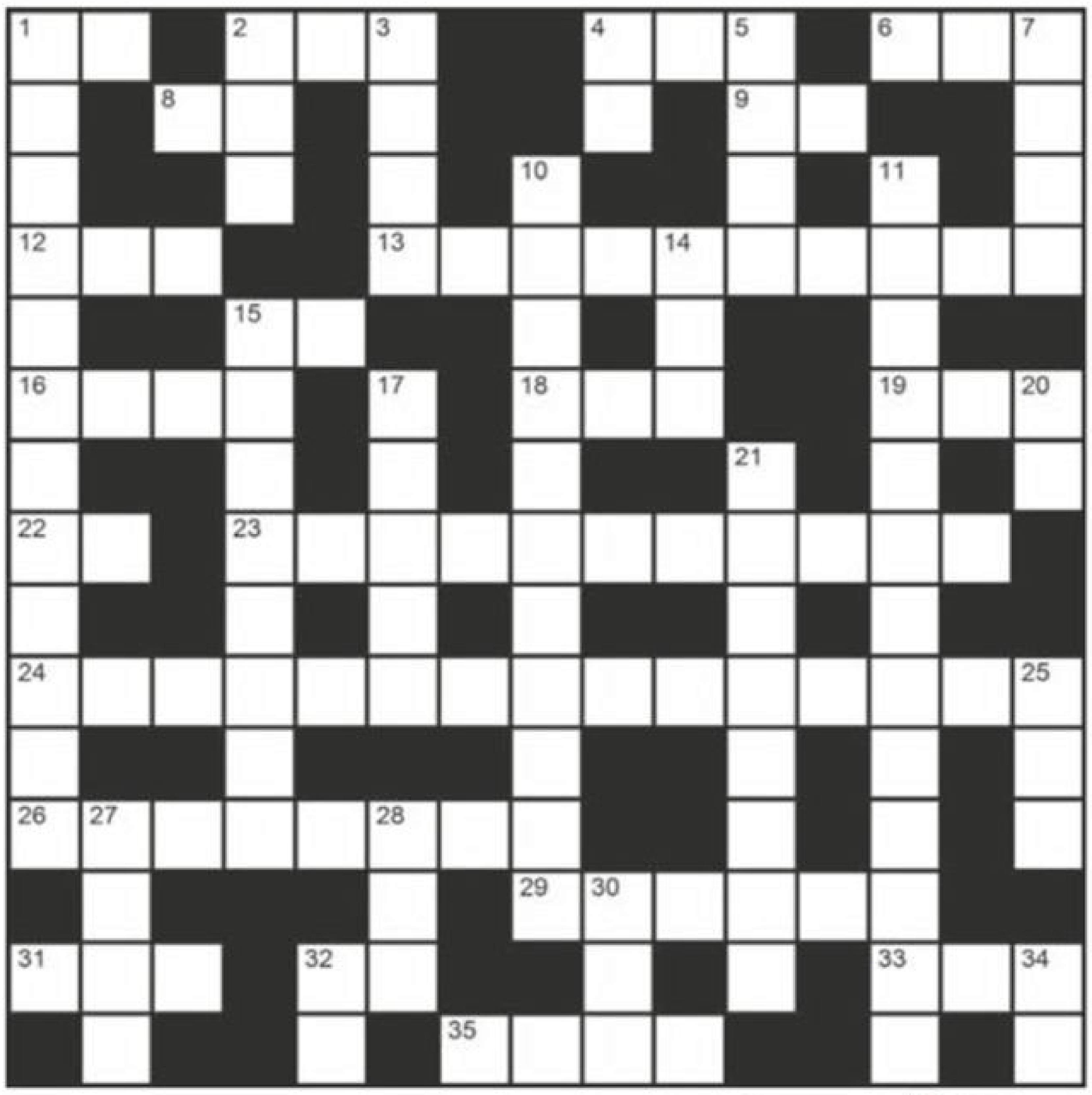
YOU ARE:

0-3 A fish out of water
4-5 Treading water
6-7 A fountain of knowledge

Answers: 1a, 2b, 3b, 4b, 5c, 6a, 7a

EVERY MONTH, A NEW CHALLENGE SET BY **ARCHIMEDES**

Science **crossword** *Nº 3*



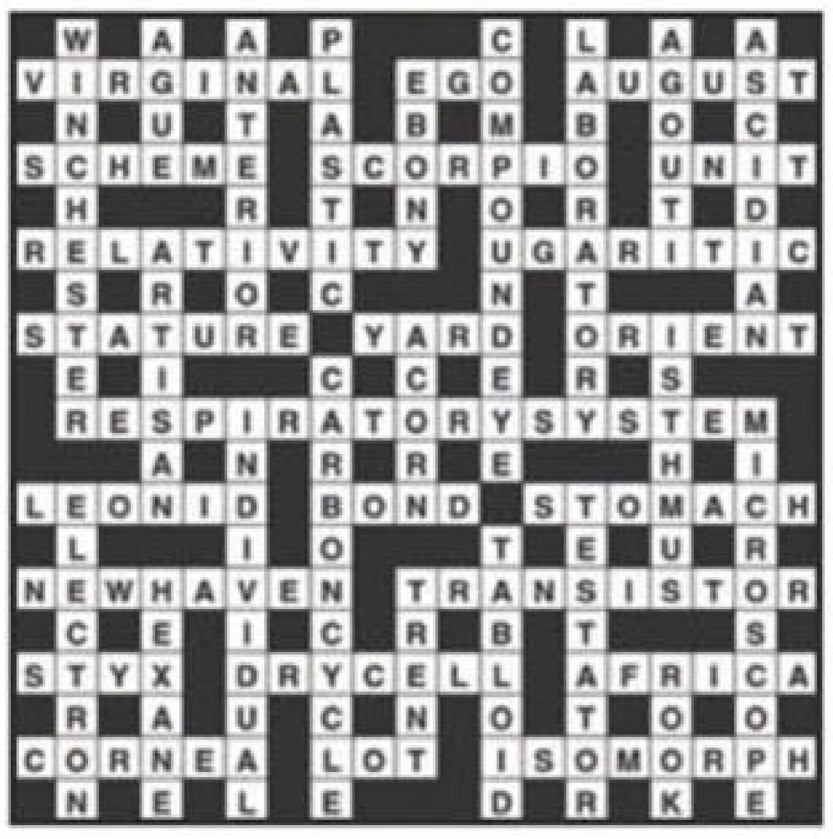
Across

1 Radioactive element named after Marie Curie's homeland (chemical symbol) (2)
2 In particle physics, the truth quark is also known as the ___ quark (3)
4 Form of computer data storage (3)
6 Contains nitrogen, oxygen etc (3)
8 Radioactive noble gas (symbol) (2)
9 Digital logic gate that generates a 1 if one or both inputs are 1 (2)
12 A core component of the Internet Protocol Suite (abbreviation) (3)
13 The scientific study of earthquakes (10)
15 Soft alkaline earth metal named after the Greek for 'heavy' (chemical symbol) (2)
16 A weather ___ shows wind direction (4)
18 Fluid transported in plants (3)
19 In physics, a physical quantity produced by moving electrically charged objects (abbreviation) (3)
22 Last element in the lanthanide series (chemical symbol) (2)
23 Duck-billed dinosaur that lived on two continents and had a spike-like crest (11)
24 Passage along which food passes during digestion, from mouth to anus (10,5)
26 Form of carbon made by heating organic matter in the absence of oxygen (8)
29 The smallest of the Galilean moons (6)
31 The number of oxygen atoms in a water molecule (3)
32 Metal discovered in Copenhagen in 1923; used in control rods (symbol) (2)
33 The duration of a Martian day (3)
35 Fine-grained earth mostly composed of minerals called phyllosilicates (4)

Down

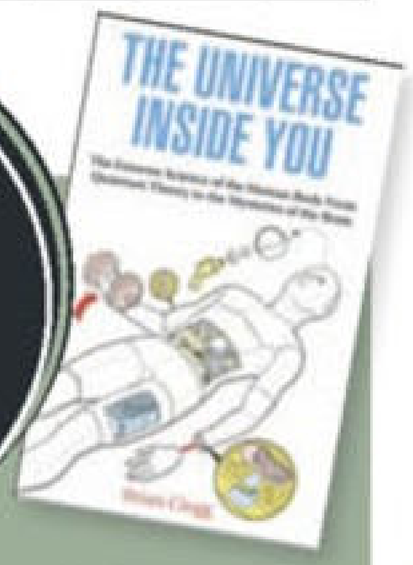
1 Solar cells generate electricity through the ___________ effect (12)
2 Chemical compound known for its explosive properties (abbreviation) (3)
3 Spherical seeds eaten as vegetables (4)
4 The __ factor is found in blood (2)
5 The term given to single-channel audio in a music system (4)
7 Crystal used in lasers (4)
10 Uranium-238 is __________ by fast neutrons but cannot sustain a chain reaction (11)
11 A physical property of a group of atoms bonded together (9,4)
14 A star chart is one of these (3)
15 Name of the first process used to mass-produce steel at low cost (8)
17 In particle physics, the heaviest of the leptons (5)
20 Important metal in blood (symbol) (2)
21 Unconfirmed dinosaur genus, derived from the Greek for "deceptive tooth" (8)
25 Familiar trigonometric functions: sine, cosine and ___ (abbreviation) (3)
27 Contains the metacarpal bones (4)
28 In binary code, if 1 is 'on' 0 is ___ (3)
30 Type of radiation emitted by a 'black light' (3)
32 Frequency is usually measured in __ (abbreviation) (2)
34 SI derived unit of luminous flux (2)

Solution to No 140



Congratulations to Nick Dale (Lancaster), Susan Wilton (Northumberland) and D Sanders (Dumfriesshire) who correctly solved May's puzzle (No 140) and each receive a copy of the BBC's *Planet Dinosaur* on DVD.

Win
A copy of The Universe Inside You by Brian Clegg



The first five correct solutions drawn will each win a copy of The Universe Inside You *by Brian Clegg. Entries must be received by 5pm on 26 July 2012, after which the winners will be randomly drawn.*

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Post entries to BBC *Focus* magazine, Summer 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to summer2012@focuscomps.co.uk by 5pm on 26 July 2012. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 82. Immediate Media, publisher of *Focus*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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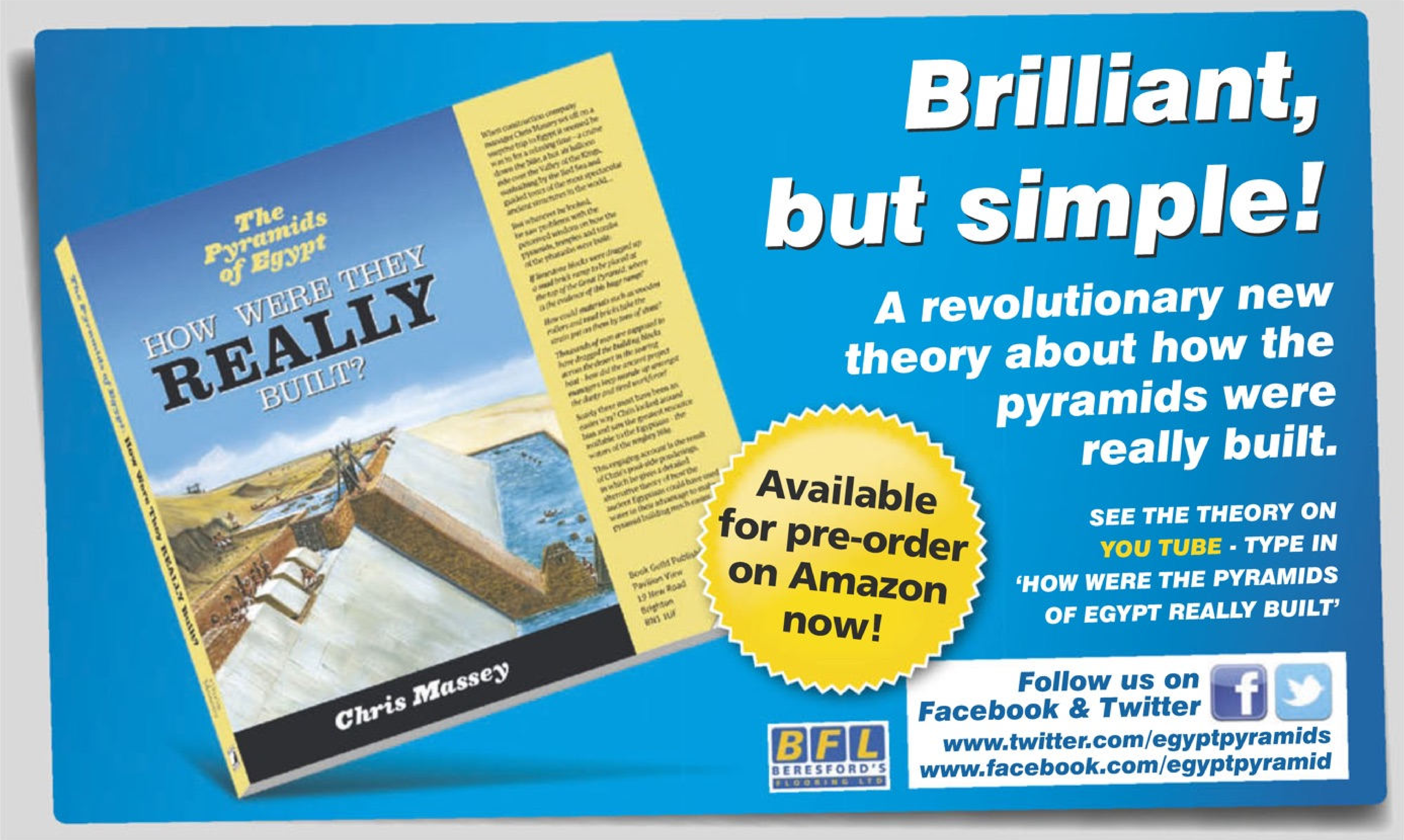
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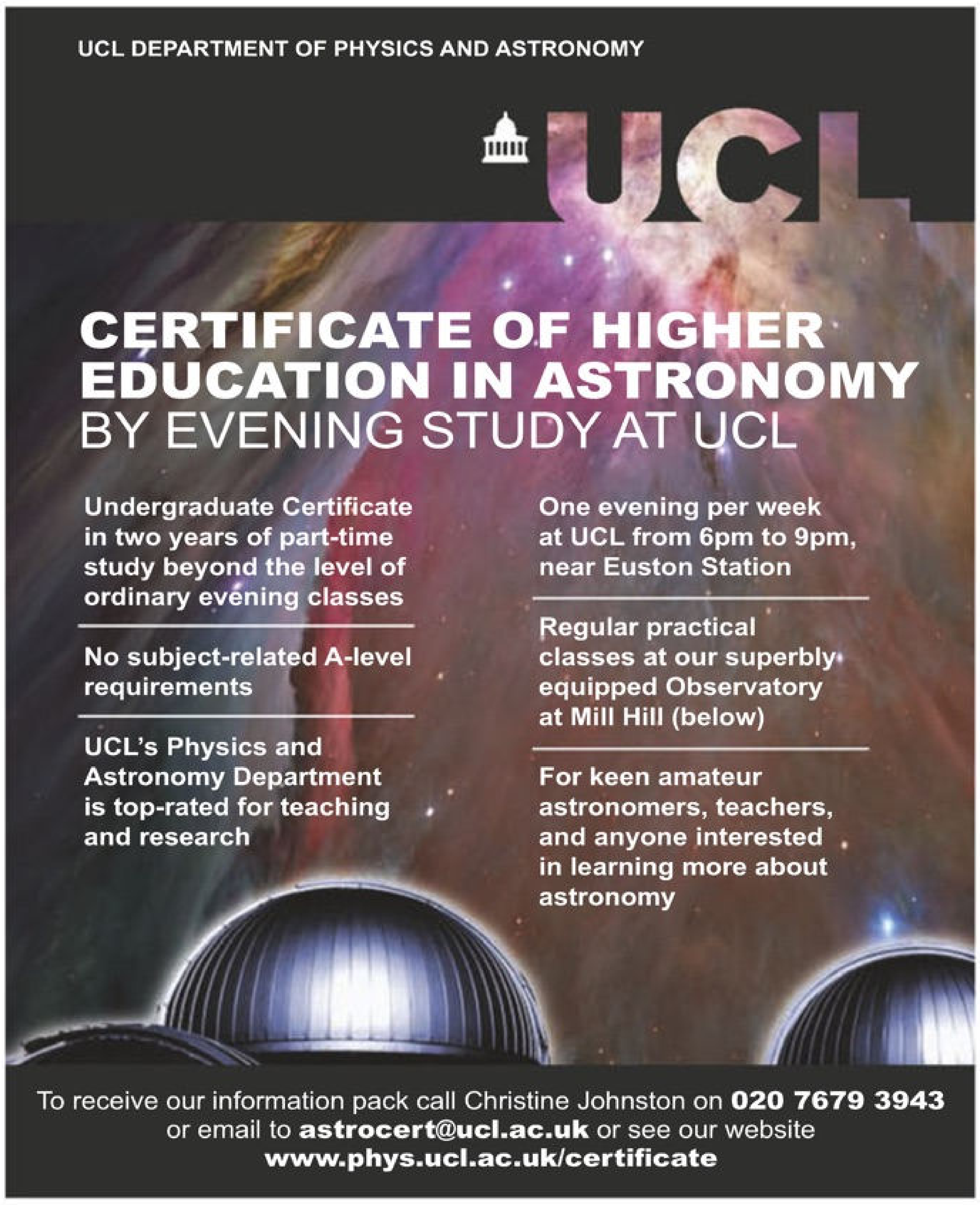

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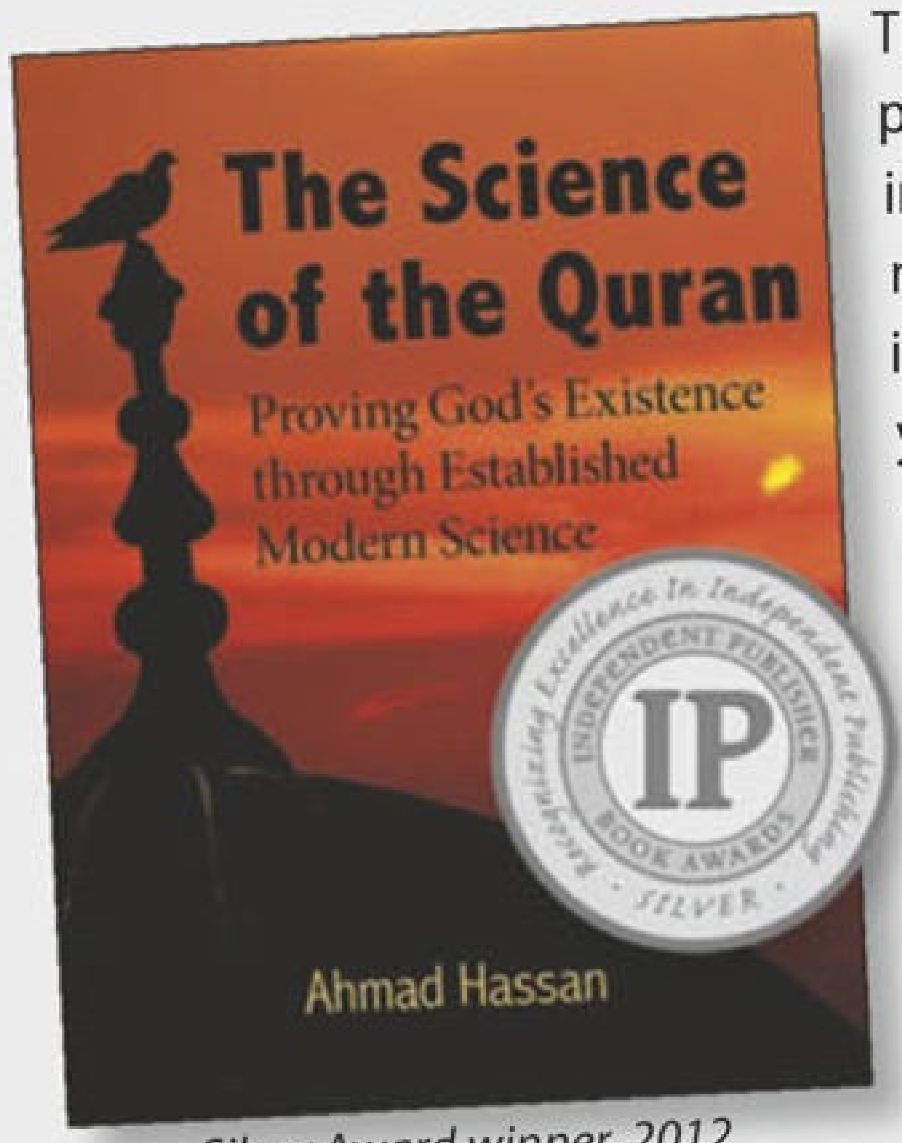
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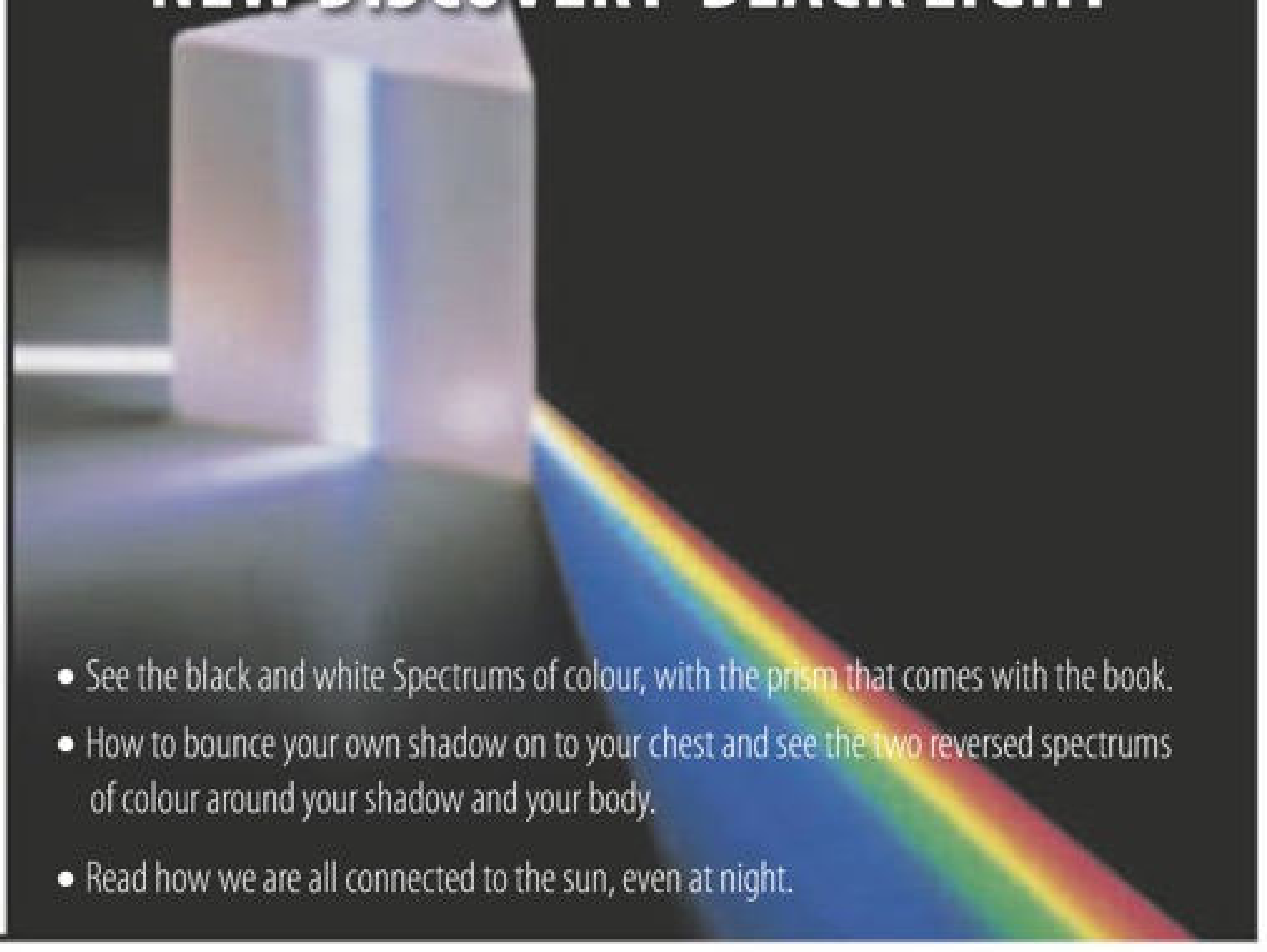

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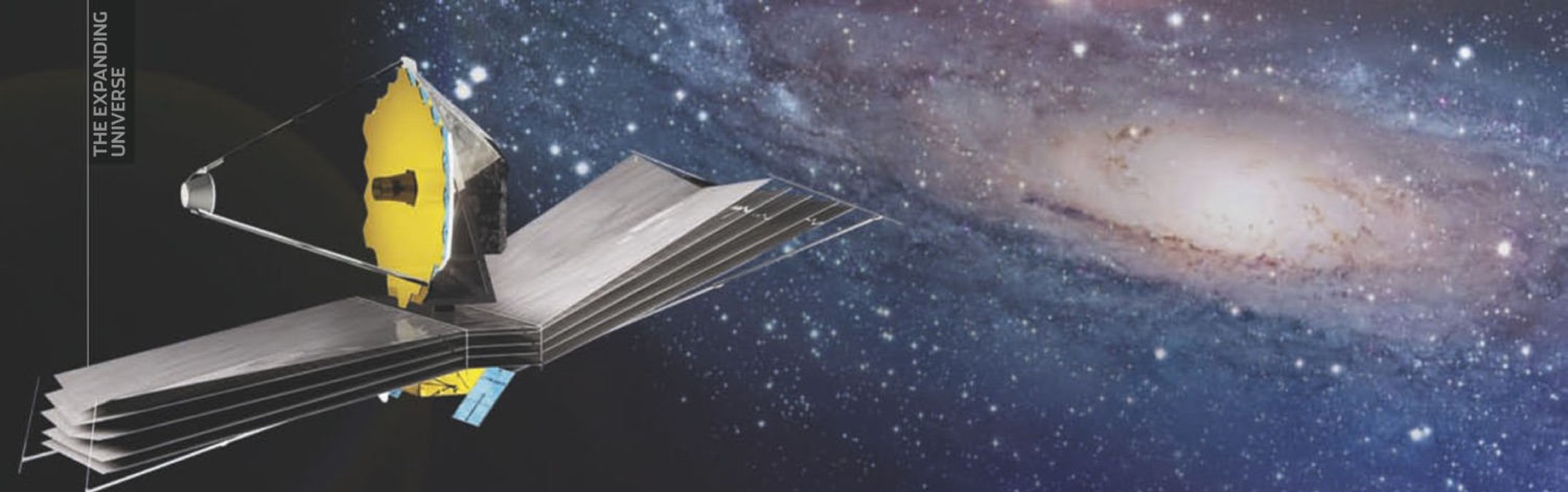

Then, Now & Next

REDSHIFT

How the discovery of the expanding Universe led astronomers to the first stars

WORDS: KELLY OAKES

THEN

In 1912, Vesto Slipher took a photograph of our neighbouring spiral galaxy, Andromeda, that helped change our view of the Universe forever. Working at the Lowell Observatory in Flagstaff, Arizona, Slipher showed that Andromeda was rushing towards us at great speed. When he did the same for other spiral galaxies, he discovered that most of them were actually moving away, not towards us.

Slipher used an instrument known as a spectrograph to take a snapshot of the particular colours corresponding to different wavelengths of light coming from a galaxy. He found that the wavelengths of the light from galaxies moving away from us had been shifted towards the red end of the visible light spectrum. This effect is called redshift.

Astronomers didn't recognise the significance of Slipher's discovery until a few years later when Edwin Hubble linked a galaxy's speed, or redshift, to its distance from Earth. It became obvious that more distant galaxies were moving away from us faster. Hubble concluded that this was happening because the Universe itself was expanding.

NOW

The deeper we look into space, the further back in time we see. So today astronomers look for galaxies with high redshifts to peer back into the early Universe. A galaxy called UDFy-38135539 has the highest confirmed redshift of any found so far. It was discovered by the Hubble Space Telescope in a small region of space in the constellation Fornax. The light from UDFy-38135539 was emitted less than 600 million years after the Big Bang and took 13.1 billion years to reach us. It is the first galaxy astronomers have studied that comes from the time when the first stars and galaxies were beginning to form.

Astronomers think they have spotted another galaxy with an even higher redshift – one that existed just 480 million years after the Big Bang. But Hubble has been pushed to the limits of its technical ability. To confirm this more distant discovery, astronomers will have to wait for Hubble's successor, the James Webb Space Telescope, which is due for launch in 2018.

NEXT

The James Webb Space Telescope (JWST) will be able to see further back in time than Hubble. Astronomers will use it to study the formation of the first stars and galaxies in greater detail than ever before.

Light from these early galaxies has been stretched so much on its journey to Earth that when it reaches us it is in the infrared part of the spectrum. JWST is optimised to see infrared light so that it can study very high redshift galaxies, and hopefully shed light on the end of a period in the early Universe known as the Dark Ages.

During this time, space was full of neutral hydrogen gas. But there were no stars or galaxies. Then, around 400 million years after the Big Bang, something kick-started their formation. Astronomers don't yet know which objects were the first to form, or where and how they began to fill the Universe with light. Perhaps some of the photographs from JWST will change our view of the Universe as much as Slipher's did. ■

Clockwise from top left: the James Webb Space Telescope, the Andromeda Galaxy, Lowell Observatory and Vesto Slipher

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